DISCOVERY

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DISCOVERY

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The Progress of Science

Further Outlook—Improving

A FEW weeks ago the apparent hardening of the attitude of the United States on the question of the atomic bomb and the utilisation of atomic energy gave rise to serious anxiety for the future. The result of the Washington conversations between Mr. Attlee, Mr. Truman and Mr. Mackenzie King shows a definite move on the part of the U.S.A. away from the position of atomic isolationism which would have led to disaster in the long run. One is led to the conclusion that the outcome of these talks constitutes no mean triumph for Attlee. The final statement, although far from ideal, warrants some lightening of the heart.

Of particular importance in the nine-point statement is the fourth clause: *We declare at the outset our willingness, as a first contribution, to proceed with the exchange of fundamental scientific information: and the interchange of scientists and scientific literature with any nation that will fully reciprocate*. The most important point here is that there is no mention of the atomic bomb so this policy, presumably, applies to other branches of science besides nuclear physics.

Clause 5 claims, rather too sweepingly, that the fundamental scientific information on atomic energy has already been published and that the same course will be followed with any new information of this character which may be acquired. As a principle of long-term policy one can only deplore the attempt to draw the line between fundamental and technical knowledge, but it is difficult not to approve of the distinction in the present case. The clause referring to that particular point is No. 6, which lays down the principle of keeping secret details of practical industrial applications of atomic energy until effectively enforceable safeguards for its peaceable use are in being. When this has been secured, a willingness to share this information reciprocally with any other of the United Nations can come into play. In the meantime a Commission is to be set up without delay to prepare recommendations for international control, including specifically the extension of exchange of basic scientific information, measures to control atomic energy so as to restrict it to peaceable uses, the elimination of the atomic bomb and other indiscriminate weapons from national armaments, and the provision of safeguards (such as inspection) to secure the objective just mentioned.

The process envisaged is one of separate stages, each securing a basis of confidence on which the next may rest.

This is well enough so far as it goes, but the statement never even considers the possibility of going as far as completely free exchange and publication of scientific information. What the conference seemed to understand by free exchange of scientific information was the interchange at a high level, and under seal of secrecy, of scientific information between *governments*. It is to be hoped that the threats voiced by Mr. Bevin and Mr. Churchill recently in the House of Commons against scientists who would not toe the national line are not an expression of the permanent policy of Anglo-American government. If they are, they will meet with the determined opposition of the whole of the scientific profession throughout the world.

There the matter rests for the moment: the next step is the promulgation of the findings of the International Commission, and we feel relief only to the extent that such a Commission is to come into being.

UNESCO and International Co-operation

THE problem of re-establishing, and improving upon, the international co-operation in science that existed in 1939 has been a constant preoccupation of all scientists throughout the war. Before the war, international co-operation took two main forms: one, the interchange of ideas and the formulation of future plans for individual or national work at international conferences and congresses; the other, the co-operation in international organisations concerned with such matters as the control of epidemics, quarantine regulations, locust control and so on.

The preparations for the creation of a United Nations Educational Scientific and Cultural Organisation—*UNESCO* for short—are well under way. So far as the Science in it is concerned, there has been an expressed consensus of opinion that augurs well for the future. The

general unanimity existing between British scientists over *UNESCO* emerged from the five articles published in *Nature* last month (in the November 10th issue).

It is clear that the present state of the world demands a greatly enhanced degree of international co-operation as compared with the pre-war period. It must be made easy for ideas and their creators to meet and to co-operate. The international scientific conferences must be restarted: their value has always been, not so much in the official programmes of meetings but in the opportunities which they provide—and which can be provided *in no other way*—for personal contact between colleagues whose normal places of work are widely separated. There are many scientific problems which cannot be adequately discussed by even the most rapid correspondence, and such a technique of telecommunication is as far from the ideal as a postal game of chess. In addition, ordinary facilities for individual travel and for visits by scientists to institutions abroad must be facilitated. Where travel remains difficult, or a need arises for constant consultation between widely separated institutions, then contact by correspondence, assisted by the cultural and technical liaison bodies such as the British Council, the Cultural Division of the U.S. State Department, *VOKS* and scientific attachés must be rendered as simple and easy as possible.

The United Nations Organisation will also involve the extension of the international scientific organisations, for it is clear that such bodies as the Radio Communications Organisation, the Civil Aviation Board, the Food and Agriculture Organisation, the Petroleum Board, the International Health Board and the Drug Traffic Commission, in addition to the bodies coming directly under *UNESCO*, will all have scientific problems continually in mind.

It is obvious what needs to be done and, for once, it does not seem as if there is going to be very much difficulty about doing it. There is, however, one very important pre-requisite, namely that scientific knowledge should be free and unfettered. The most striking test case is, of course, that of the atomic bomb and atomic energy generally, but this is only the most crucial of many examples. It is particularly crucial because the knowledge concerned is most fundamental. We might, for example, be able to tolerate, although with a considerable degree of frustration, secrecy in radar, for here the body of fundamental knowledge involved concerns a relatively limited field of science. We should hamstring that branch of science if such a policy were tried, but to try the same policy with nuclear research would be fatal. International co-operation in science would be reduced to a farce: all the scientists concerned would either regretfully abandon the field or become involved in secret rivalry. Nor would it be any good to try to differentiate between technical "know how" and scientific knowledge. Such a line cannot be drawn and any attempt to do so would lead to a ludicrous situation in which Scientist A could discuss a certain subject because he had found out about it on his own, while Scientist B, who discovered the same thing earlier, would be gagged by his local official secrecy.

A second point brings us back to the organisation of international scientific unions. Hitherto they have taken the form of meetings of national delegations—a sort of League of Nations in miniature. If this form is adhered to in the future it is likely to lead to considerable difficulties over the problem of the enemy nations. The United Nations have committed themselves to the standpoint that they do not indict the nations but the individuals responsible, but even so it seems impossible in the foreseeable future that German or Japanese scientists can be admitted to international conferences as representatives of Germany or Japan. On the other hand, it is well known that the behaviour of scientists in these nations ranged all the way from those who disgraced their calling by active support of regimes whose mere form made them hostile to all that science stands for, to those who maintained a heroic resistance to the assaults of their tyrranical oppressors. The first have debarred themselves permanently from international co-operation: the second will be welcome and honoured by their colleagues in other countries. It seems clear, then, that some modification of the old "League" structure will have to be made so as to admit, as distinguished and honoured *individuals*, those scientists who at peril of their lives maintained their scientific integrity within the enemy countries.

A third point arises as the logical consequence of the pre-occupation of *UNESCO* with scientific problems and of the concern of many departments of the work of the United Nations with scientific matters. As has been said, in pre-war days a good deal of the scientific co-operation which went on was merely the co-ordination round a conference table of work being done, and which probably would have been done in any case (although rather less well), even if the conferences had never been called. To this extent co-operation was a façade rather than a reality. What now seems necessary is the establishment of co-operation at the laboratory bench. If knowledge of atomic energy is to be made international, for example, then surely the logical thing is that the research should be done internationally in an international scientific institute financed and controlled by the United Nations. There are possible difficulties, of course: if a nation felt itself scientifically supreme and was secretly bent on world dominance, it might allow only its second-rate men to work at the international laboratory, but as long as the published work from the international institute showed a clear lead over what has been achieved in secret by any single nation, there would be a strong deterrent to a breach of the peace.

The same is true of other fields in science. Governments of nations take a hand in science where an important national problem needs solving which it is not in the interest of any one private organisation to attempt to solve. Similarly *UNESCO* ought to take a hand by setting up its own research organisation to deal with any important scientific problem transcending the capacities or desires of a single nation. For example, disease, famine, locust infestation and their consequences know no frontiers, and international organisations have arisen to deal with them. Many more examples must exist. It is impossible, for example, to see all the heavens from one point on a spherical earth, so that astronomy is perforce international; following the argument already sketched, this would lead to the establishment of an internationally manned observatory which would result in more effective international co-operation. Each scientist will, however, see the problem in terms of his own science, and it will become clear that this policy of a super national research

foundation is one which, if adopted, would lead to a real fructification of international science and help to secure its application only in the interests of progress.

Fifty Years of X-rays

A FULL discussion of the impact of the discovery of X-rays upon the development of science would occupy many large volumes. At first sight it is not clear why this should be so: X-rays are, after all, exactly similar to light waves, except that their wavelength is shorter; why should this extension of the known wavelength range downwards produce results so strikingly different in quality from those which had been obtained before?

Ordinary visible light is of such a wavelength that, when it falls on certain structures of a regular repeating form, such as, for example, a series of parallel lines ruled on a glass plate with a separation of about one hundred thousandth of an inch, then certain effects occur which are dependent on the fact that the size of the structure is about the same as that of the wavelength of light used. In the case quoted, the light reflected in different directions from such a ruled plate, or *diffraction grating*, is of different colours, so that this device may be used to split light up into its constituent colours. A diffraction grating for visible light is unsuitable for X-rays several thousand times shorter in wavelength, for in this case the separation of the lines would have to be of molecular dimensions. Such structures cannot be artificially constructed, but they do occur in nature: the regular structure of a crystalline substance is of the right order of dimensions, and crystals can

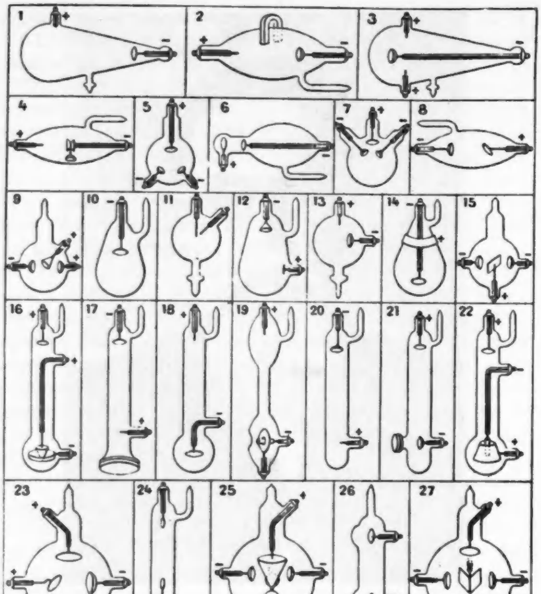
The first X-ray photograph—of Frau Roentgen's hand.

Wilhelm Conrad Roentgen (1845–1923)

be used to diffract X-rays, or to put the matter the other way round, the observed diffraction patterns produced when X-rays fall on crystals can be used to deduce the crystalline structure. Here roughly is the basis of one enormous field of application, the investigation of crystal structure by X-rays.

The second property of X-rays, which forms the basis of another field of application, is that the absorption coefficients of substances for radiation are different for different wavelengths. This ought not to surprise us: a piece of red glass, for instance, is transparent to the long-wave (red) visible light and opaque to short-wave (blue) light. Ordinary glass is transparent in the visible region but opaque to ultra-violet light—the name given to light of wavelengths just shorter than the shortest—i.e. the bluest—visible light. X-rays are extremely penetrating and, when passed through a complex structure such as a limb or some complicated manufactured article, a shadow picture of the internal structure is produced because its various parts, differing either in thickness or in chemical nature, absorb different proportions of the X-rays passing through them. This effect is the foundation of the best known application of X-rays, used in fields as far apart as medical diagnosis and the detection of cracks in castings. (Several interesting industrial radiographs were reproduced in the article "Photography—An Industrial Tool", DISCOVERY, October 1945, p. 308.)

The third field of application depends on another property of radiation which varies with wavelength. It will be recalled that modern physics gives a dual picture of radiation, as a *wave* phenomenon and as a *particle* phenomenon. Roughly speaking, we may say that a beam of radiation consists of the motion of a series of packets of energy, the distribution of these packets following a wave pattern. The light is most intense at the "crests" of the waves, and there the energy packets crowd most



There was no delay in following up Roentgen's discovery. This was reflected in the variety of Roentgen tubes built in 1896 (from *La Nature*, Nov. 21, 1896).

densely, while in the troughs they are sparsely distributed. With visible light, experiment can reveal the wave structure to the eye, but with X-rays the phenomena are on a scale thousands of times smaller still and these facts are less directly demonstrable.

The energy packets are called quanta and differ in size according to the wavelength of the radiation with which they are associated, being larger the shorter the wavelength. Quanta of sufficiently high energy can eject electrons from atoms and cause chemical change—i.e. the breakdown of molecules—but for each type of interaction a certain minimum size of quantum is required. A very few quanta of sufficient size, i.e. a very feeble beam of short wave radiation, will produce changes of this kind, although very slowly, but a most intense beam of long wave radiation will not produce the slightest change. The reason is that in the latter there are no quanta of sufficient energy to produce the change and the rules of the game do not allow a number of them to gang up together.

The application of this last property which is most familiar is in the use of X-rays for the treatment of cancer. It appears that quanta of sufficient energy can upset the molecules in the cells of the cancerous growth and so destroy it. The treatment must, of course, be applied with great skill so that the rays are concentrated in the growth, since X-rays also affect normal cells, and can cause disease and burns as the early X-ray workers discovered sometimes at the cost of their lives. Geneticists, too, have found that this property of X-rays gives them a research technique, and they are in the position of being able to cause mutations by altering chromosomes with the use of X-rays.

This brief sketch of the applications of X-rays cannot end without some reference to Wilhelm Conrad Roentgen, who, one Friday evening in the autumn of 1895 became the first man to detect X-rays. He was then fifty years of age and, but for his luck in making the discovery and the energy he put into exploiting his initial observation, might have achieved no more than the fame accorded to a rather undistinguished professor of physics. His career from his birth a century ago to his great discovery, fifty years ago, was one of hard work, a steady professional advancement, and a series of sound contributions to physical knowledge. On that memorable day —November 8, 1895, to be exact—Roentgen noticed that a screen of barium platinocyanide showed evidence of the incidence of radiation although the only possible source was a gas discharge tube which was wrapped in black paper. This type of tube consists simply of a glass enclosure containing a gas at a low pressure and fitted with two electrodes between which a large difference of electric potential is applied. What was happening, as we now know, was that electrons repelled from the negative electrode or cathode impinged on the glass wall of the tube where their energy was converted into X-rays. These tubes were in wide use at the time as the result of the researches of Sir William Crookes on electrical discharges in gases, and X-rays must have been produced on many occasions before. Roentgen simply had the luck to notice their effects, and the energy and skill necessary for further investigations. In early experiments he put his hand in the rays and saw a shadow picture of the bones on the barium platinocyanide screen (which glows when X-rays impinge on it). The

Public interest in Roentgen's discovery was spontaneous—and there was no lack of jokes about it. (Cartoon from *Life*, February 1896.)

first X-ray picture ever taken was that of his wife's hand. After seven weeks' work he communicated, on December 28, a paper to the Physical Medical Society of Wurzburg and this immediately attracted world-wide notice. At that time Roentgen was not clear what was the nature of these new rays, and for some time he believed them to be longitudinal vibrations of the ether, in contrast to the transverse vibrations of ordinary light. He therefore gave them the equivocal name of X-rays. Already by February 1896, work was being done in America and claims of earlier discovery of X-rays became rife. Four days after the discovery was known in America, X-rays were used (perhaps typically of those days) to locate a bullet in the calf of a patient's leg, and only a year later the first X-ray cinematograph picture—of a frog's leg—was made.

Our knowledge of the early history of X-rays and the circumstances of the discovery are due mainly to an enterprising reporter, Mr. H. J. W. Dam, representing *McLure's Magazine*, who secured, early in 1896, an interview with Roentgen in his laboratory. Dam describes him as a "tall, slender, and loose-limbed man whose whole appearance bespeaks enthusiasm and energy."

The importance of Roentgen's discovery was immediately recognised by the scientific world and he was awarded the Nobel Prize in 1901. Public recognition was, however, not always so discriminating. One cartoon appeared, for example, representing a rustic reaper having his X-ray photograph taken—the resulting photograph coming out as a skeleton grasping a scythe! X-ray-proof underwear was advertised, and the following music hall ditty appeared:

X-actly So

The Roentgen Rays, the Roentgen rays.
What is this craze?
The town's ablaze
With this new craze
With this new phase
Of X-ray's ways.
I'm full of daze
Shock and amaze
For nowadays
I hear they'll gaze
Thro' cloak and gown—and even stays,
These naughty, naughty Roentgen rays.

But who are we to be critical of them when the atomic bomb has brought so much nonsensical print in its train?

Readers interested in biographical details about Roentgen should consult Otto Glasser's *Wilhelm Conrad Rontgen* (Bale Sons & Danielsson, 1933).

The Department of Meteorology

MUCH publicity has been given to the great advances made during the last few years in certain branches of science, notably Radar, which were of great operational importance. Much attention, in terms of trained man-hours, has been paid to meteorology, whose operational importance has been equally great. Little progress, however, has been made in our knowledge of the fundamental processes which govern weather conditions, and, as a result, accurate weather forecasting is only possible for sbort periods—often less than 24 hours.

Many of the reasons for this deficiency are suggested in a Memorandum entitled *The Department of Meteorology*, which has been recently issued by the Meteorological Office Branch of the Institution of Professional Civil Servants. It also contains concrete suggestions as to how this position can be rectified. The first point made is the need for continuing the existing system of a unified Meteorological Service in this country. The working data required by the weather forecaster are simultaneous observations of weather conditions over at least half a hemisphere. The collection and rapid transmission of such a mass of data requires an elaborate international organisation with agreement on such points as codes, times of observation and of W/T transmission. The meteorologist, of all scientists, depends most on international co-operation. Owing to war-time developments in technique and methods, considerable changes in the peace-time schedules are inevitable. Agreement will be reached all the quicker if the British representatives, speaking for a unified service, can give a lead, as they so often have done in the past.

Directly arising from this well substantiated claim for centralisation in the United Kingdom is the suggestion of a combined United Kingdom—Colonial Meteorological Service. Before the war the Dominions and the Colonies, under the Colonial Office, maintained their own separate Meteorological Services. The war-time demands of aviation could not be met by the Colonial Services, and the extra personnel had to be supplied by the United Kingdom Service. This increased demand, though to a lesser degree, will continue. Further, under the pre-war scheme meteorological personnel in the Colonial Service had to serve long periods abroad—often in trying climates, with but little leave—in order to ensure their pension rights. With a unified service, tours of duty abroad could be regulated and the available man-power disposed so as to promote the greatest efficiency.

The main reason for the present preoccupation of the British Meteorological Office with short-range forecasting is that since 1919 it has been under the administrative control of the Air Ministry and there has therefore been a definite bias to considering the needs of aviation first and of other users second. The first result of this was the splitting of the Meteorological team in 1937 when the work of the Meteorological Office's Naval Division was transferred to the Admiralty. In other countries, notably the U.S.A. and Germany, where the needs of agriculture and industry have been more adequately considered, much more attention has been paid to the development of long-range forecasting. The Fisher Committee in 1919 recommended that the Meteorological Office should be controlled by a body on which all user interests were represented. The I.P.C.S. go further and suggest that the Meteorological Service should be placed under the direct control of the Lord President of the Council, who is regarded as the Minister "who can view in a disinterested manner the meteorological claims of all user interests".

Some special problems arise when the question of personnel comes to be considered. The meteorological officer (especially the forecaster), to give the most efficient service, has to be in very close contact with his "customers", of whom under existing conditions the Services are the most numerous. Many Service personnel have a prejudice

against civilians working in Service establishments. For this and other reasons it was decided in 1943 to militarise the meteorological office and all personnel at operational stations, if not already enrolled, became, overnight, members of the Meteorological Branch of the R.A.F.V.R., whilst personnel employed at non-operational stations remained civilians. This caused some heartburning as to the differences of pay and allowances and especially the sudden doubling of the leave entitlement of the Service man, whilst the civilian directorate of the meteorological office showed often a surprising ignorance of the King's Regulations and Air Force Acts, which now governed the great majority of the personnel of the office. A satisfactory solution to this problem of uniformed and ununiformed personnel in the same service is of far more importance to the general harmony and therefore efficiency of a Meteorological Service than is allowed for in the I.P.C.S. Memorandum. Differences of pay and privileges which were accepted under war-time conditions, will not be so willingly borne in the future, if the Service chiefs still require the meteorological personnel attached to the Services to be in uniform.

The recommended method of recruitment is through a Central Board under the Civil Service Commissioners, with candidates for the Scientific Officer grade possessing a first- or good second-class Honours degree and those for the grade below, provisionally called "Meteorological Officers", something better than a pass degree. This is a desirable standard for the near future, and so is the proposed scheme of training. There are at the moment numerous war-time entrants without the academic qualifications given above, who are desirous to continue in the Office and who have shown themselves thoroughly proficient whilst advancing through several grades to that of Forecaster. Are these competent and trained meteorologists to be demoted and perhaps lost to the Office or, if academic qualifications are rigidly insisted upon for forecasters, are they to be given help to attain them? Sabbatical years are suggested for Scientific Officers. Why not also for selected war-time entrants to enable them to gain the necessary paper qualifications? The alternative is to force these meteorologists, if they still wish to continue in the Office, to do what is condemned elsewhere in the Memorandum, to indulge in "arduous work outside office hours".

Finally comes the very important question of research. In the last twenty years few of the major advances in meteorological knowledge have been contributed by British meteorologists owing to the lack of adequate facilities and opportunities. The whole previous policy of the meteorological office with its emphasis on short-range aviation forecasting has been against the encouragement of research, which "was for practically all meteorologists a spare-time occupation". Reference is made in the memorandum to the proposals already on foot for the establishment of a Meteorological Research Institute under the Universities Grants Board and, in addition, it is proposed that there should be a special Research Division of the Service concerned primarily with research into the fundamentals of meteorology, whilst each of the proposed divisions of the Service (Agriculture, Industry, Royal Air Force, etc.), should have a Research Section dealing primarily with "the problems arising from the demands made in that division by its user interests" and with a fluid complement of men "passing from operational duties to research only". These proposals cannot be too highly commended. They are not an ideal to be attained if possible; they are an *essential*, which must be reached if British meteorology is to regain its position in World Science, and if the British Meteorological Service is to make as efficient contribution to the demands of peace as it did to the more specialised, and in the main short-term, demands of war.

A Glimpse of Operational Research

THE phrase "operational research" has been on the lips of scientists for a considerable time, and in the scientific world everyone knows roughly what it means—the study of weapons and equipment under actual battle conditions so that the maximum effectiveness in use may be secured. It is a wide field, covering the study of the employment of units singly and in groups, the design of equipment so as best to fit the man of average size, shape and capabilities, and the development of drills and instruction systems so that high efficiency may be acquired as rapidly as possible. It obviously has all sorts of implications for the design of domestic equipment and of machinery for use in industry, and it has links with such subjects as "scientific management". In fact, in so far as advances in applied science are going to give us devices to make hard work easier, operational research is of the first importance in any consideration of the impact of science on the ordinary man, for the technique and experience of such research should result in equipment easy to use, and in smoothing the path to easy and efficient use.

So far, however, there has been no authoritative account of the whole field of operational research, and no indication that the experience gained during the war is to be put to anything but warlike purposes. The Press handouts on the subject, although fragmentary, are of the highest interest. For example, at the end of October the Air Ministry issued an account of the work of scientists at Fighter Command. Reference is made to the way in which scientists first impinged on operations, when they were called upon at first, to operate, and later, to supervise the operation of radar stations. Late in 1940 night fighters first began to carry radar apparatus for the detection of enemy bombers, and it was found that, although some aces achieved excellent results, others found difficulty with the complex equipment. On many operational flights civilian scientists took the place of R.A.F radar operators to study the behaviour of the equipment and the methods by which the successful aces got results. As the result of actual combat experience they were able to produce an elementary text-book on radar operation and started a school for instruction in the use of airborne radar and in the tactical method calculated to produce the most effective results. This course has been followed whenever new radar sets have been introduced, and these have been tested by scientists under combat conditions and optimum methods recommended. In this way, by backing up the operational aircrews, the Service scientists helped considerably to improve the efficiency of the night fighter force.

Again, when ground control of fighter interception was introduced, scientists studied its operation before turning it over to the R.A.F., thus securing its function as an effective military factor from the outset. As was to be

Continued on p. 373

The first part of this article, by the Naval Assistant to the Deputy Controller (Research and Development) at the Admiralty, deals with Asdic, radar at sea, and the radio-proximity fuse. The second half, to be published in next month's issue, gives an account of sea mines and counter-measures. The writer wishes to acknowledge with appreciation the great help given to him by officers of Admiralty departments and experimental establishments.—Ed.

Science in the Naval War

Lieutenant-Commander S. J. BROOKFIELD, R.N.V.R.

THIS war has seen the entry of scientists into every aspect of the Navy. One would expect to find them working on such obvious problems as the design and construction of ships, aircraft, weapons and warlike equipment of all types, but they have been called upon to solve also many of the problems peculiar to the use of any equipment at sea. Even galleys and laundries bring their own difficulties when they have to be installed in ships where consideration of space and weight are so important. And even such details as the position of seats, back-rests, foot-pedals, binocular eyepieces, headphones, etc., for operators having to remain on duty for long periods, have taken the attention of research physiologists who, at other times, have joined with ventilation engineers and constructors in studying the habitability of ships' compartments and the effect of habitability conditions on the mental and physical efficiency of personnel.

These vast programmes of research and development in every field have created an unprecedented demand on our scientific and technical man-power. Our resources have had to be allocated in the most economical way according to a strict priority system based on the operational requirement for new equipment and on the technical promise of attaining the desired result. Naturally this has led to the emphasis on our work being in quite different directions from those in which the enemy has placed stress on his. For instance, to decrease the vulnerability of his U-boats he has required torpedoes of much greater range and speed; accordingly his man-power expended on research and development in this field has been many times ours. On our side we have had to concentrate our efforts on developing means to detect and locate his submerged U-boats, surface ships and aircraft, and on protecting our ships against all possible types of mines. I propose to refer to some of our developments in these fields where we have outstripped the enemy.

Submarine Detection by Asdic

The Asdic was probably the Navy's greatest technical achievement between the two wars. It derives its name from the initials of the Allied Submarine Detection Investigation Committee which initiated, towards the end of the last war, the first experiments that contributed to Asdic design. From then onwards a keen team of naval scientists worked on the problem of submarine detection in the shore-based H.M.S. *Osprey* at Portland. They kept up their enthusiasm for the work despite the technical isolation from other scientists imposed on them by security requirements, and despite the flagging public interest in naval equipment in those days. Thanks to them our ships were fitted with Asdic sets when war came in 1939. Since then, as "H.M. Anti-Submarine Experimental Establishment", they have occupied war-time quarters at Fairlie, Ayrshire, and their efforts have ensured that the Navy remained technically well ahead of the enemy in the field of underwater detection.

The apparatus depends on the well known principles of echo-sounding. A sound wave is transmitted into the water and, from the time taken for an echo to be reflected back, the distance to the reflecting surface is known. The echo-sounder directs its pulse downwards and the sea bed can be relied on to give a strong echo, but the Asdic must be designed to search for a small moving target of whose position we have no primary knowledge. Moreover, the ship in which the detector is fitted may be rolling, pitching, yawing, and making a great deal of noise

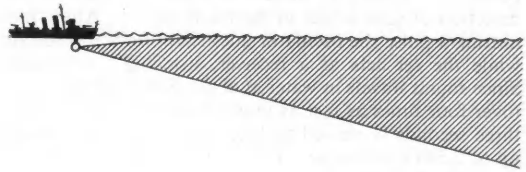


FIG. 1.—Asdic beam under homogeneous water conditions.

It is interesting to note that the idea of pointing an echo-sounder forward to look for obstacles ahead was first suggested, and patented, in 1912; the proposal for installing such a device was directly inspired by the *Titanic* iceberg disaster. With the oscillator available at that time the ranges obtainable were too short to be useful, and the patent was allowed to lapse. Allied experiments in 1917 showed little promise until it was suggested that the piezo-electric* property of a quartz crystal might be used to produce a highly efficient supersonic oscillator. With this innovation the ranges leapt up. Twelve sets were ordered for installation in ships, but the war ended before they could be put into operation. In the twenty years that followed, the *Osprey* team, although hampered by cuts in personnel and lack of money, developed the apparatus to a stage far in advance of any other nation, and many

* The piezo-electric effect is a phenomenon, exhibited by certain crystals, of expansion along one axis and contraction along another when subjected to an electric field.

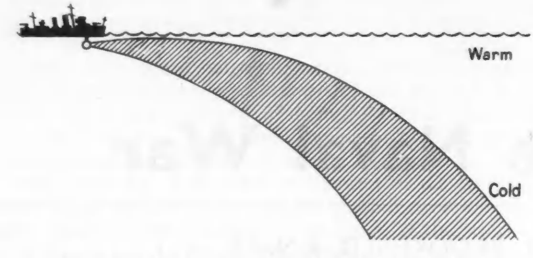


FIG. 2.—Refracting conditions; surface water warm.

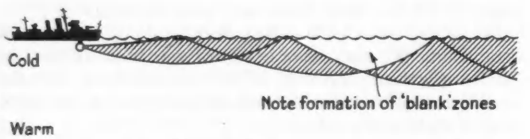


FIG. 3.—Refracting conditions; surface water cold.

years ahead even of those Allies who had collaborated with us in the early developments.

The Asdic oscillator emits brief continuous wave pulses of supersonic frequency in a thin conical beam a few degrees wide directed horizontally. In homogeneous water conditions this beam undergoes some reflection at the surface and searches the area shown shaded in Fig. 1. Temperature gradients in the sea produce refracting conditions which result in the swept area being as in Fig. 2 or Fig. 3. (Either of these two cases may lead to non-detection of submarines in the blank areas). After transmitting a pulse the oscillator goes silent for a few seconds while the set acts as a receiver, listening for an echo. Since sound travels in water at about 5,000 feet per second (over four times as fast as in air) a silent period of about three seconds is needed to listen for echoes from objects up to 2,500 yards away. This period can be varied to suit the tactical situation.

The oscillator is housed in a flooded dome below the keel (Fig. 4). In the earliest sets the oscillator had to be suspended in the water by hanging it over the side of the ship, and it was not the least of the battles of the pioneer days to persuade the Director of Naval Construction, who, of course, must always fight any suggestion of impairing hull strength, to cut a hole in the bottom of ships to provide a home for the new detection apparatus.

The oscillator is attached to the lower end of a vertical shaft which extends upwards to the lower deck. It may thus be trained in azimuth (i.e. rotated around a vertical axis) by the operator above by means of an electric motor with suitable control arrangements. In practice, a search is carried out by transmitting automatically on bearings at every five degrees between 80° green to 5° red, and then from 80° red to 5° green.* The operator listens through loudspeaker or headphones, in which a "ping" is heard when an echo returns from a reflection of the searching beam in the sea.

The operator must be skilled to differentiate between the echo from the hull of a submarine and that given by any other heterogeneity in the medium, such as shoals of fish,

* Red is *Port*, Green is *Starboard*.

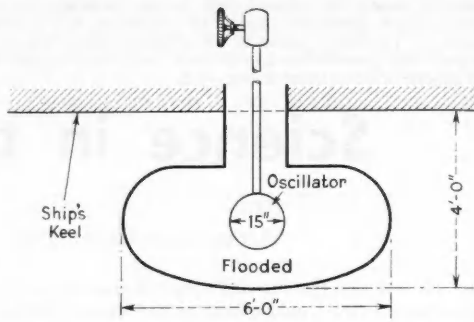


FIG. 4.—Asdic dome, broadside view of section; the figure is purely diagrammatic, only the order of dimensions being indicated.

bubbles, wakes of ships, and of course, the sea bed. In very rough seas there may be echoes from the troughs of large waves, and to add to these difficulties there may be a "quenching" effect in rough seas when the motion of the ship is sufficient to cause the formation of a pocket of air around the dome which will prevent any pulse going out into the water.

Having found a target on one bearing the operator continues transmission on this bearing and a few degrees on each side of it, and he switches over to the visual recorder. In this instrument chemically treated paper is fed out of a tank at every transmission of the oscillator, and each time a stylus is drawn across the paper from left to right. The output from the power stage of the amplifier is tapped from the loudspeaker terminals, rectified, and applied to the stylus, the circuit being completed through the chemically treated paper and the body of the tank containing it. Any increase in output, e.g. an echo, will result in chemical action at the point of contact between the stylus and paper, and a mark will appear on the latter. The paper is pre-impregnated with a solution of potassium iodide and soluble starch. The passage of a current through the paper from stylus to tank releases free iodine which is deposited on the record making a dark mark. When the oscillator emits a pulse the stylus is at A (Fig. 5) and in the following three seconds it travels from A to B. The distance AB will then represent a range of 2,500 yards, and a mark on the trace at P will indicate an echo from a target at a range of 1,500 yards. From B the stylus flicks back to its starting-point, and the paper moves, so that after the next pulse the stylus will move over CD. In subsequent transmissions on the same (or a nearby) bearing the echoes represented by Q.R............V may be obtained. Since the range of the target is measured along AB, and the passage of time along AM, the gradient of the line PV relative to the axis AM will represent the speed of the target relative to the ship.

The photograph (Fig. 6) shows a specimen trace from an Asdic recorder. The faint marks along each line are caused by reverberations in the water. Looking at the target echoes from bottom to top (since the paper in the recorder moves "downwards" the bottom of the trace was made first) it will be seen that we appear to lose the target occasionally and then to contact it again. This is because

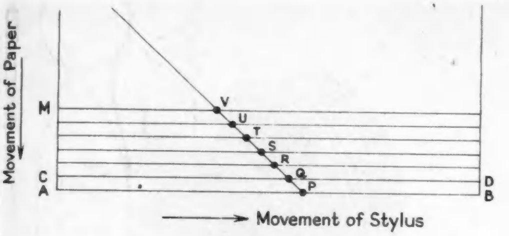


FIG. 5—The diagram illustrates manner of operation of an Asdic recorder.

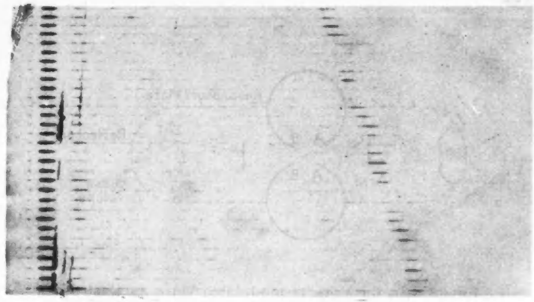


FIG. 6.—Part of a specimen trace made by an Asdic recorder.

the transmissions have been made on different bearings. The operator has been sweeping across the target until the beam misses it, and then sweeping back again so that alterations in target bearing will quickly be noticed. The range in this case is closing and the direction in which the line should be drawn to indicate relative speed of target can clearly be seen.

Thus the bearing, range, and relative speed of the target are determined and passed to the bridge where the Commanding Officer selects an attacking course and determines the moment to fire the pattern of depth charges.

This is the technique which the *Osprey* team had prepared for our crews to use in the first round of the Battle of the Atlantic, and which enabled them to inflict a sharp defeat on the enemy in the early stages. The secrecy with which this twenty years of research, development and production work had been carried out was a model in security methods. The components of the sets had been distributed to so many different firms for manufacture that no individual firm could tell for what purpose they were intended. The final assembly was done under strict security conditions in an Admiralty establishment. Seldom has secrecy been so perfectly maintained over so many years, and seldom has it paid such good dividends as it did in this case. For some time the enemy thought that, as in the last war, we were relying on hydrophones to listen for the underwater sound from the submarine's engines, and he devoted much effort to reducing their noise. But our Asdic sets were, of course, just as effective however silent the submarine became, and his early counter-measures were quite useless. At last he developed "Pillenwerfer", large chemical balls for the submarines to eject, which produced streams of bubbles giving an Asdic reflection, in the hope that our operators would follow the decoy instead of the target. But they were already trained to distinguish between the echo given by the bubbly wake of a submarine and the submarine itself, so that they soon learned to detect the decoys. Since a bubble target is not moving horizontally through the water it will be approached at the speed of the ship, and the operators soon learned to become suspicious of any target whose rate of approach was nearly equal to the ship's speed.

For every counter-measure used by the enemy to attempt to escape detection our counter counter-measure was ready, and the technical superiority won for us by our research and development teams enabled the crews of our escort vessels to continue sinking U-boats throughout the whole of the war.

Naval Radar

Two naval scientists collaborated in the early Air Ministry radar experiments at Orfordness and Bawdsey in 1935, and shortly afterwards a small party started work at H.M. Signal School to develop radar specifically for naval requirements. There the research and development team grew so fast and to such a vast extent that early in the war it was given an independent existence as the Admiralty Signal Establishment which now absorbs over half the total research and development effort of the Navy. This expansion was found necessary in spite of the closest liaison being maintained with the corresponding teams in Air Ministry and War Office establishments because of the problems peculiar to installations in ships. Seldom could a set developed for another Service be used unaltered in H.M. ships.

Naval development of radar was greatly concerned with aerial design and was profoundly influenced by the limitations imposed on the height, size and weight of aerial that could be mounted at the masthead. Considerations of wind resistance and the effect of topweight on ship's stability have been important from the start, and a glance at the complexity of aerial arrays on the mast of a modern warship will show to what degree the problem of size has grown now that radar sets are used for such a variety of purposes (Fig. 9). The need for stabilising aerials to counter the roll and pitch of the ship and for rotating them to search through 360° added mechanical problems and extra weight. Great sharpness of radar vision was required to distinguish between distant objects close together, and this demanded sharpness of the radar beam which, for an antenna of given size, is proportional to wavelength. Dipole aerials were used half as long as the wavelength employed, so that everything pointed to the necessity for developing radar on ultra short wavelengths which would allow the use of small aerials with narrow beams. Consequently naval scientists tended to concentrate on centimetric radar technique.

The design of sets under the stringent conditions imposed by naval needs often led to important advances in technique (e.g. accurate range-taking) which have been of great value to the other Services. But perhaps the greatest naval contributions to the subject as a whole have been in the field of valve development. From the start in 1935, H.M. Signal School, Portsmouth, undertook to make for the Air Ministry the silica valves which went a long way towards solving the problem presented by heat dissipation

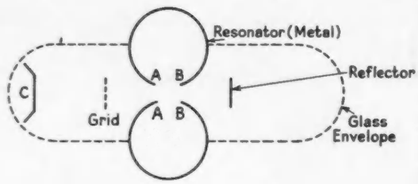


FIG. 7.—In the velocity-modulated valve an electron beam emitted by the cathode C is attracted by the D.C. potential of the resonator casing. Some of the beam passes through a hole in the resonator. Assume that the resonator is in an oscillating state. The inside of the resonator can be regarded as a tuned circuit of high magnification, the inductance being the path from A to B, and the capacity that across AB. There will be an alternating field between A and B, and the beam in its passage across the path AA BB will be made to travel alternately faster and slower. The charged particles composing the beam will be "bunched" into groups of varying density. (This is why it is called a VM valve—the density of the beam is modulated by changing the velocity). This beam travels on until it comes near to the negatively charged reflector. Here the beam is turned back and travels into the resonator gap again. If the length of the path from AA to the mirror and back, and the velocity of the beam (dependent on the accelerating voltage) are properly adjusted, the beam returns to the gap AA, BB when the phase of the field at AA. BB is so related to the passage of the bunched groups that energy extracted from the beam helps to maintain the oscillations in the resonator. The resonator having the properties of a high magnification tuned circuit, the frequency remains very stable, after the valve has been given time to warm up.

in high-powered valves. Since then the Admiralty has been responsible for major advances in valve development carried out by its own establishments and by the University and industrial teams which it has sponsored. Outstanding among these developments have been the modern magnetron (Fig. 8) and the velocity-modulated valve (Fig. 7) which made possible the great advances in centimetric radar after 1940. (A picture of the velocity-modulated valve appeared in Sir Robert Watson-Watt's article in DISCOVERY, September, 1945.)

But centimetric radar seemed far off in 1937, and putting aircraft detection first among naval radar requirements it was decided to concentrate on a set operating on the longest wave for which it was deemed practicable to erect a rotatable dipole aerial system at a ship's masthead. One mast carried the transmitting aerial and the other the receiving aerial, their rotations being synchronised. Trials of development models in H.M.S. *Rodney* and H.M.S. *Sheffield* in 1938 were most encouraging, and valuable experience was gained not only in aircraft detection but also in the location of surface vessels. An improved transmitting valve with a new type of filament enabled a re-designed model with three times the power to be made in June 1939. This forerunner of hundreds of air-warning sets of the same type was fitted in H.M.S. *Curlew* in August 1939. So that before the war began we had in commission a ship equipped with a complete air-warning set of a design which has won especial honours for its reliability.

This was Type 79, which operated on 7½ metres at a power of 70 kilowatts, detecting high-flying aircraft at ranges up to 85 miles, and aircraft at 1000 ft. up to 20 miles. Although designed for aircraft warning it gave

FIG. 8.—Forced air-cooled magnetron. This particular valve has the phenomenal output of 450 kw. (*Photograph by courtesy of The General Electric Co. Ltd.*)

detection ranges up to 15,000 yards against surface vessels. It was succeeded by Types 279 and 281: the latter, on 3.3 metres, had greater power and range, and with the addition of beam switching, an accurate ranging panel which permitted its use for gunnery purposes. Later models had both aerials rotating on a single mast. These sets were extensively fitted in battleships and cruisers, but owing to weight and size could not be fitted in smaller ships.

The arduous duties of escort vessels on convoy work led to a pressing need to fit them, too, with means of warning against air attack, and with means of detecting E-boats and surfaced submarines at night. A combined warning set, Type 286, with less elaborate aerials and smaller and less complicated apparatus, was adapted from an Air Ministry ASV set*. It underwent many modifications in service and was eventually replaced in 1942 by an all-naval model which was such a triumph in compact design that it was known as the "suit-case" set. This worked on 1½ metres at 100 kilowatts and had a very high power-size ratio. It detected aircraft at ranges of 40 miles, and gave useful ranges on U-boats.

But the problem of U-boat detection was solved when the development of centimetric radar led to Type 271. The prototype of this 10 cm. set went to sea in the Flower Class corvette, H.M.S. *Orchis*, in March 1941. Its success was immediate: it detected targets even as small as a submarine's periscope at useful ranges. Later 10 cm. sets with power-rotated aerials and PPI gave good warning, too, against very low-flying aircraft. Such discrimination was made possible by the narrowness of the intense beam of microwaves produced by the magnetron valve. In the Type 271 set, a trigger valve (a gas triode) fires a modulator valve 500 times a second. The modulator valve causes a negative flat-topped voltage pulse lasting 2 microseconds to travel along a line to the magnetron valve in the aerial house. The magnetron oscillates at 3,000 megacycles per

* The following abbreviations for radar terms are used in this article: AI, standing for Air Interception; ASV, Air to Surface Vessel; IFF, Identification of Friend or Foe; PPI, Plan Position Indicator.

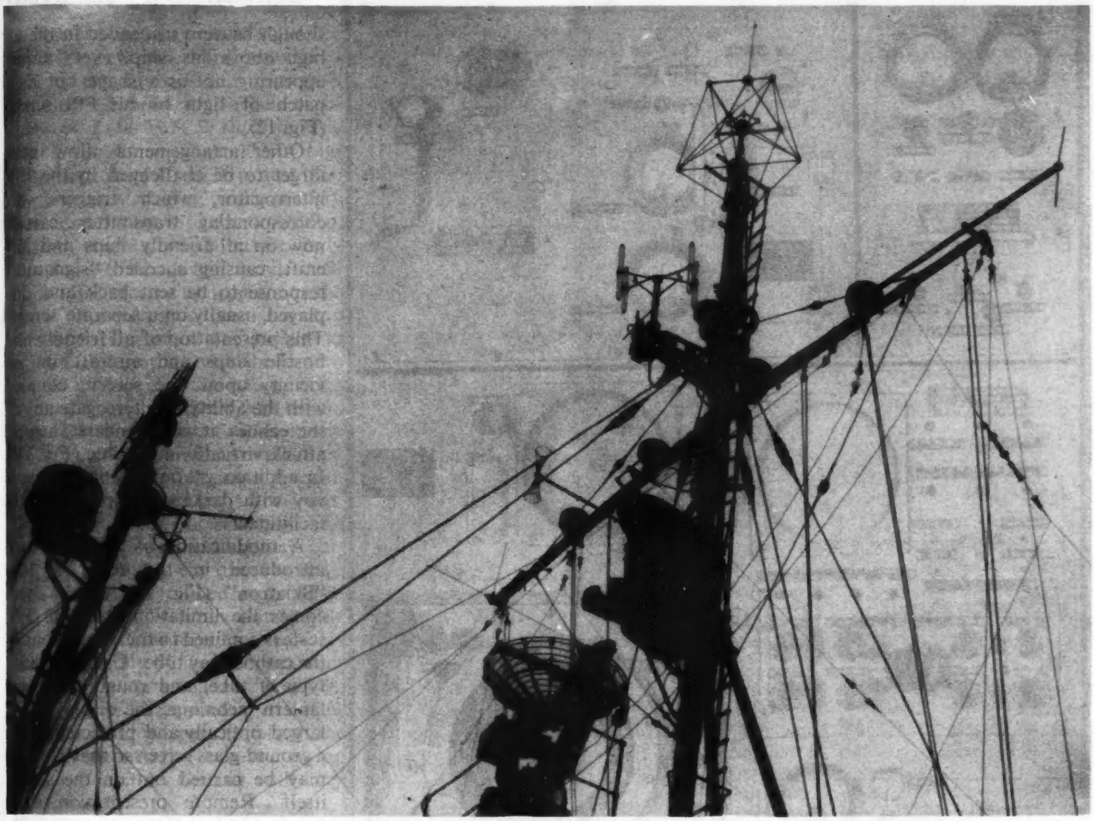


FIG. 9.—Radar aerials on ship's mainmast.

second and produces microwaves which travel along a wave-guide, are reflected off a parabolic cylindrical mirror and are radiated in a narrow beam towards the target. The echo from the target is picked up by a similar mirror above the first and focused on a small dipole aerial. The signal passes to a crystal in the mixer unit where it is heterodyned with an oscillating voltage from the local oscillator, a special velocity-modulated valve, to produce a frequency of 60 megacycles per second, which is amplified, rectified, and applied to the cathode ray tube in the receiving office, and in some cases to a distant tube. The range is measured in the normal way by observing the position of the echo on the scan, as a vertical hump on a horizontal trace (against a printed scale). Bearings are taken by training the aerials by hand until the echo is at its maximum and then reading from a scale on the aerial training gear.

In this set three components alone absorbed a great deal of development effort and ingenuity: the magnetron, the waveguides and the velocity-modulated (VM) valve. The holder for the magnetron also supports a permanent magnet of field strength 1,500 gauss. The direction of the magnetic field is perpendicular to the electric field set up by the anode-cathode potential, and as a result, when H.T. is applied the electrons around the magnetron filament take up oscillating orbits. The frequency at which the valve oscillates is primarily determined by its internal dimensions. Maximum power output is obtained when the magnetron is oscillating at the frequency determined by its own resonant properties and when the output line is tuned to this frequency.

Cable transmission lines are not suitable for passing the microwaves from magnetron to aerials, and waveguides are used since they cause far less attenuation. They consist of hollow metal tubes (rectangular or circular cross-section) through which the energy travels in the form of electromagnetic waves, as in free space: it is confined to the centre of the guides since ultra-short waves will not penetrate far into a conductor. The theory of wave-guides was worked out by Lord Rayleigh forty years ago but it had never before been possible to produce transmission of sufficiently short wavelength to warrant their use in place of cables. By ingenious design it has been found possible to produce bends, sudden or gradual, in the guide, while obtaining correct reflection at the corners. When it is required to radiate the waves into free space the waveguide is opened out into a "flare" or horn. Thus the energy radiated along the waveguide is projected into the mirror from whose surface it is reflected towards the target.

Type 271 had an immediate and lasting effect on the Battle of the Atlantic, turning it in our favour at a critical period. The U-boats on the surface at night, which had

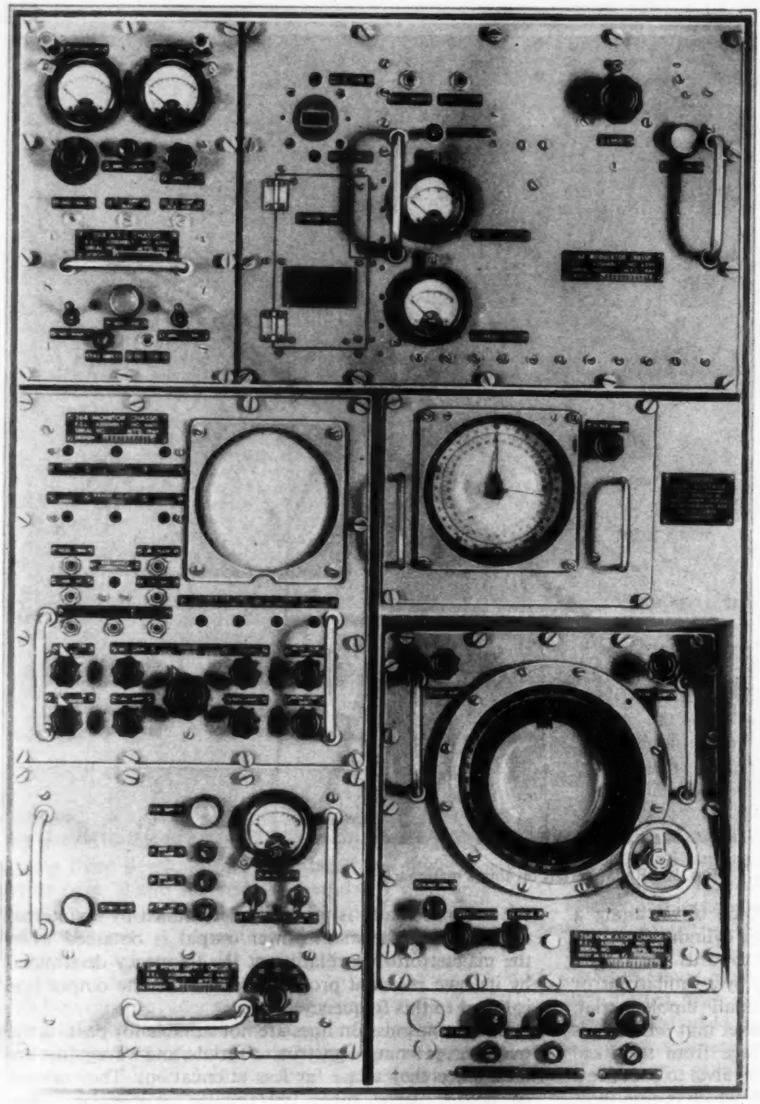


FIG. 10.—Panel of navigational radar set as fitted on merchant ships; three radar screens are seen.

previously been picking up our metric radar transmissions on their German Search Radio sets and diving to avoid detection, now found themselves detected and attacked without warning by our escorts equipped with Type 271. And the German scientists tried desperately to find the cause and the remedy, but with little success.

The introduction of PPI presentation to naval air and surface-warning sets has enabled a complete picture to be available in the ship at every moment of the disposition of own and enemy ships and aircraft in the area all around. The aerial systems, with "cheese"- or "dish"- or paraboloid-shaped metal reflectors, are continuously rotated by a power drive, and the display shows the range and bearing of all targets within the range of the equipment. The operator sees the whole situation at a glance as though he were suspended in the air high above his ship, every target appearing not as a shape but as a patch of light on his PPI screen (Fig. 12).

Other arrangements allow each target to be challenged by the IFF interrogator, which triggers the corresponding transmitter carried now on all friendly ships and aircraft, causing a coded "signature" response to be sent back and displayed, usually on a separate screen. This presentation of all friendly and hostile ships and aircraft in the vicinity upon one screen, coupled with the ability to interrogate any of the echoes at will, renders surprise attack virtually impossible (Fig. 11). In addition, station-keeping in convoy with darkened ships is greatly facilitated.

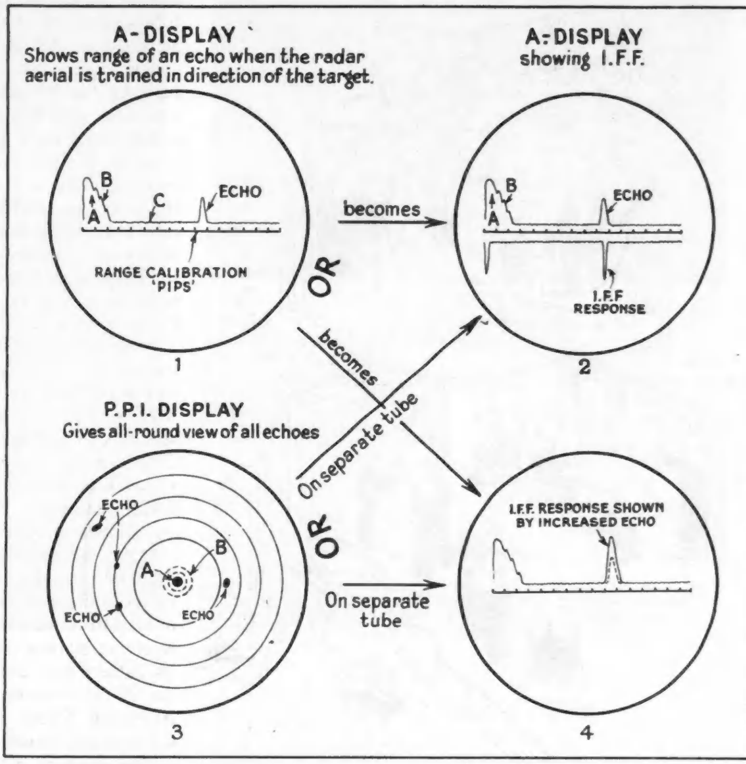
A modification of PPI has been introduced in the form of the "Skiatron" (Fig. 14) which overcomes the limitation that the PPI scale is confined to the dimensions of the cathode ray tube. Using a special type of tube, and roughly a magic lantern technique, the display is enlarged optically and projected on to a ground-glass screen so that plotting may be carried out on the screen itself. Remote presentation at a number of points is technically possible.

The importance of applying radar to naval gunnery was realised at a very early stage. The old optical rangefinders suffered from the obvious visibility limitations and could not, in any case, be used with an adequate base length on, say, the small director of pom-pom armament, whereas a great feature of radar is the accuracy of its range determination. Accurate ranging panels and bearing determination by beam switching were added to the early air-warning radar sets, but by this means only one target at a time could be dealt with and while used for ranging the set was lost for its primary purpose of detecting aircraft. It was thus necessary to provide a gunnery radar set for each director, the central control and sighting position for every battery of guns. The need for dealing with a large number of high-speed targets and for providing rangefinders on small directors led to priority being given to AA gunnery sets. But sets for surface firing also made rapid progress and in 1941 were of great value against the *Bismarck* particularly in the preliminary shadowing by H.M.S. *Suffolk*.

The great triumph of our surface gunnery sets was in the *Scharnhorst* action: the first major naval engagement in

which the main combatants never sighted each other from start to finish. Our cruisers and destroyers first located the enemy on their warning sets. Later H.M.S. *Duke of York* made contact on Type 273, a big-ship version of Type 271, and then by accurate ranging with gunnery sets scored a hit with the first salvo. Radar ranging, which in the early days was to about half a mile in 50 miles, has become as accurate as the guns themselves, so that we can know the range of the target to within a few yards and its bearing to within a few minutes. Many times distant ships have been detected on the PPI screen, identified as enemy by lack of IFF response, and fired on by batteries swung into position at the command of the gunnery sets. The shell splashes of the salvo give a radar response and the small correction necessary for the next salvo can thus be determined and applied to the guns. And eventually the success of the action has been indicated merely by the disappearance of the target "pip" on the PPI screen.

Although the problem of radar sets for AA gunnery involved the determination of an extra dimension and the need for dealing with very



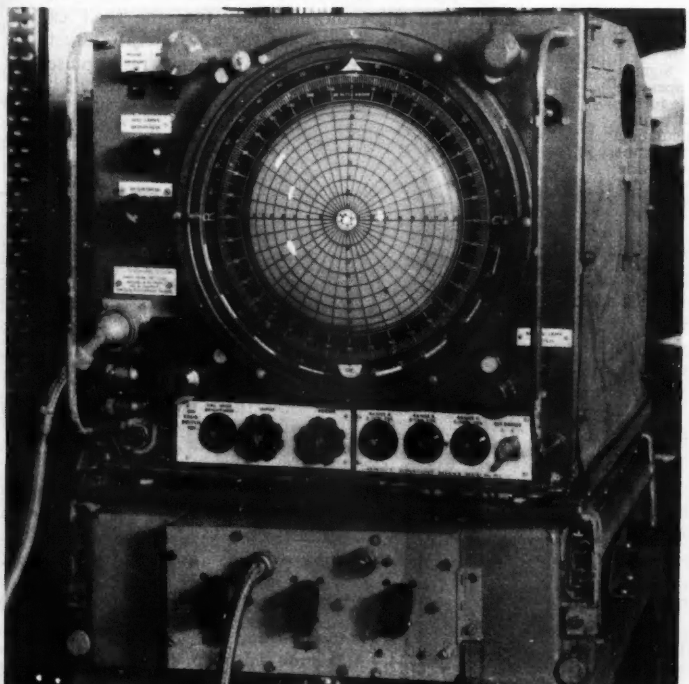


FIG. 11.—In (1) a possible target has been picked up on the *A-Display* screen; the object is then challenged by *IFF*; if friendly, the response is shown on the same tube either as in (2) or as in (4).

With a *PPI* screen on which echoes coming in from all directions are registered, any echo may be challenged on *IFF* by switching in a separate *A-Display* system trained to cover the sector of the *PPI-Display* on which the echo appears. This *A-Display* will again show *IFF* response as in (2) or (4).

In the diagrams *A* is *ground wave* due to interference caused by the force of the transmitted pulse breaking through direct to the receiver; *B*, *wave clutter*, caused by the radar beam striking and being reflected from waves near the ship—in heavy seas this might extend much farther than is shown here; *C*, *noise* or "*grass*".

FIG. 12.—(*left*) Plan Position Indicator with control unit.

high-speed targets, these sets, too, made very rapid progress in the hands of H.M. Signal School. Two types were developed, one for use with pom-poms and the other to control guns for high-angle and low-angle fire. The prototypes of these went to sea in H.M.S. *Southdown* in 1940: six months later one hundred sets had been fitted. In these early sets an operator had to turn a handle to keep a mechanically driven pointer in line with the target's echo on the range display tube, thus transmitting to the guns the range of the target and the

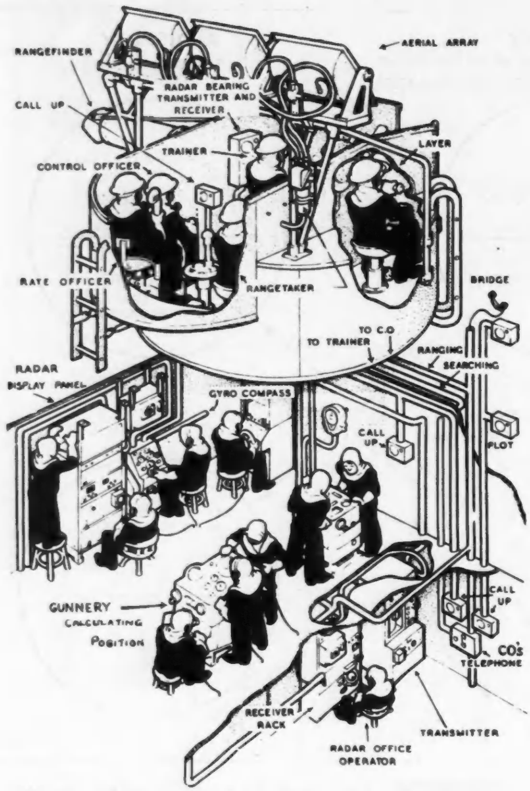


FIG. 13.—RADAR AND GUNNERY. Signals are picked up by the aerial array. The radar operator (*bottom*) sees the echo and transmits its range to the gunnery calculating position. The layer and trainer in the gun director transmit to the gunnery calculating position the bearing of the target. If the target cannot be seen the radar display panel (*left*) is used to provide a radar bearing and the guns are then able to fire "blind". The remainder of the crew are members of the gun teams.

rate at which the range was changing. Height determination was achieved at first by a multi-lobe technique, i.e. by noting the fluctuations in strength of the echoes as the aircraft passed through several lobes of the radar beam. But the centimetric sets gave a beam so sharp that in addition to providing accurate bearing determination it allowed the angle between the "line of sight" to target and the horizontal to be measured with precision. The controlled elevation of aerial together with the vertical stabilisation of high efficiency which this involved constituted one of the great mechanical problems that were solved in the achievement of direct height-finding.

Radar information on bearing, elevation and range is collected at the Director and passed to the Transmitting Station where it is fed into a computing system, and there combined with wind speed, trajectory data and corrections for own ship's movement for the complete solution of the fire control problem consisting of the determination of gun elevation and training and fuse setting. The final results are passed to the gun and are, of course, relevant to a future position of the aircraft. Blind fire has thus been achieved for AA as well as for surface gunnery (Fig 13).

The "dead-time" between ordering a fuse and firing is between 2 and 8 seconds, and either a fuse may be ordered and fired with this interval allowed for or a fuse may be ordered and loaded, the gun waiting for the firing order from the Director, which in this case waits for the target to come into the correct position for the ordered fuse. In the latter case the fuse may "mature" inconveniently early, or a long delay may be involved. The "dead-time" may thus lead to considerable inaccuracies in AA fire despite the extreme accuracy of the information supplied by the radar sets. But again radar has provided the solution, in the form of a proximity fuse.

Early in 1940 an investigation was started in this country to develop a radio fuse for AA shells. Full information on this work was later taken to the U.S.A. by the Tizard Mission and by other British scientists. There a special section of the American Office of Scientific Research and Development was set up to deal with this development which was prosecuted with the utmost vigour and with lavish resources. Special valves and components were developed, sufficiently rugged to withstand the immense shock of being fired from a gun at an acceleration as high as 20,000 g and at the terrific centrifugal pressure created by projectile rotations up to 475 per second; and sufficiently miniature to be assembled into a radio transmitting and receiving station so extremely compact that it fitted with its battery into the nose of a projectile. The result was the VT (variable-time) fuse which was used initially in the American 5-inch shell and later in British 5.25-inch, 4.5-inch and 4-inch shells (Figs. 17 and 18).

The effect on gunnery is to reduce the "dead-time" to zero. With the radio-proximity fuse the shell can be loaded into the gun ready for any aircraft target. On firing, the transmitter in the fuse emits radio pulses and

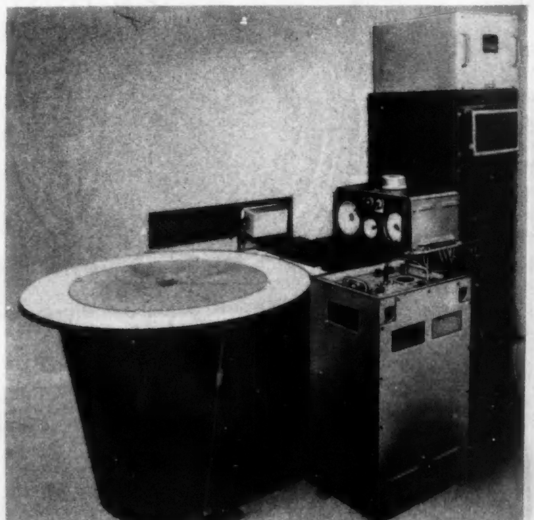
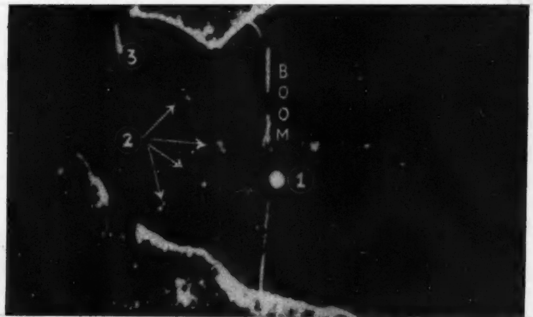


FIG. 14.—A Skiatron with a 2-ft. diameter face.



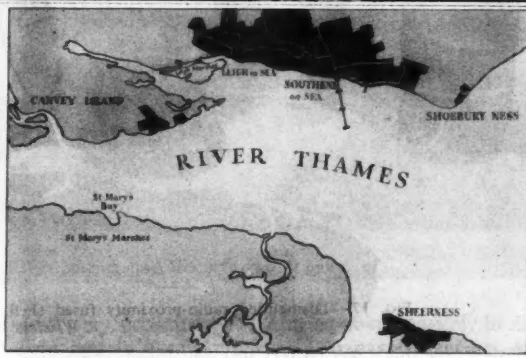
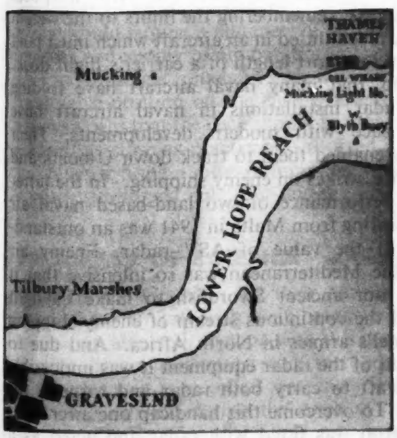


FIG. 15.—PPI display with shipborne centimetric set that will be used in merchant ships. (*Left*) Radar view of Thames Estuary at Southend; note (1) The ship that "took the picture"; (2) Other ships and buoys; (3) Southend Pier with ships lying off the end; (4) Oiling jetty on south bank of estuary. Note also the brightness of the built-up areas. (*Right, above*) This ship is coming through the boom off Southend. The map will help in identifying landmarks. (Readers may care to compare these pictures with the airborne radar picture published in the last issue of DISCOVERY.)

the receiver "listens" for echoes. These incoming impulses interact with the outgoing impulses to create a "ripple pulse" which is amplified in the receiver. When the echo reaches a value showing that the target is within functioning range* this "ripple pulse" becomes powerful enough to trigger a thyratron valve which acts as an electronic switch and through an electrical detonator sets off the main explosive charge in the projectile an infinitesimal time later.

The storage life of the early fuse was limited by the life of its dry battery which deteriorated rather rapidly, and particularly so at tropical or sub-tropical temperatures.

* About 70 feet is figure given in official U.S. report released by Office of War Information—ED.



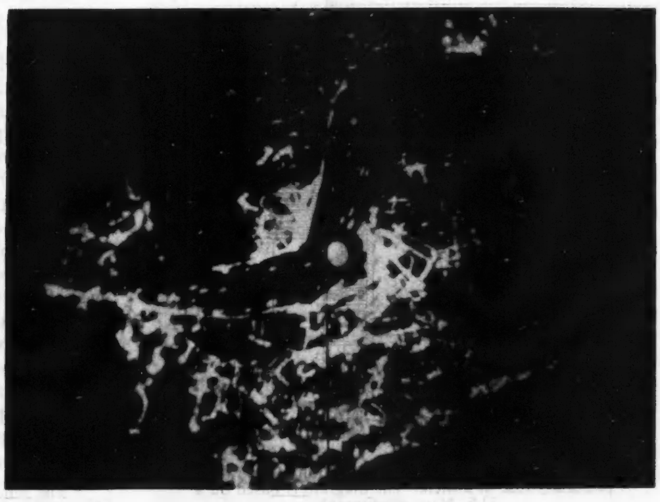


FIG. 16.—Built-up areas show up particularly clearly in this shipborne radar picture of the bend of the river around Gravesend Reach and Lower Hope Reach. The blank area on the north bank is Tilbury Marshes.

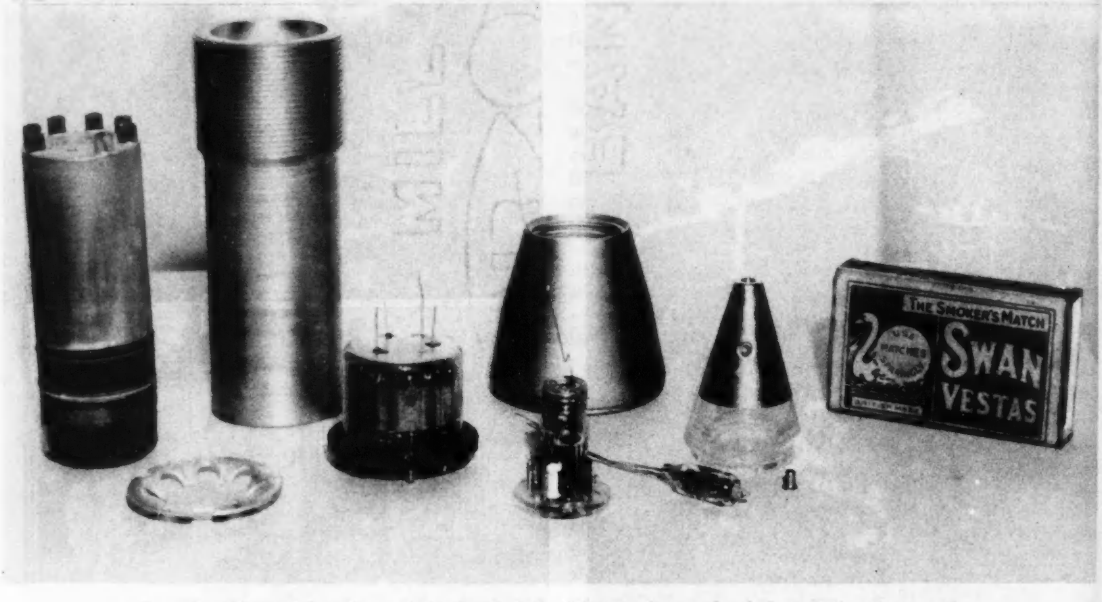


FIG. 17.—Dismantled radio-proximity fused shell. (*Photograph reproduced through the courtesy of "Wireless World".*)

To overcome this a wet battery was developed which does not become electrically active until the projectile is fired. The shock of firing breaks a small glass phial filled with liquid electrolyte. Centrifugal force in the rotating projectile causes this liquid to flow towards the outside of a cylindrical cell through a stack of thin ring-shaped plates thus producing a wet cell (known as the "reserve battery"). This process constitutes an essential stage in the "arming" of the fuse. With this non-deteriorating battery the life of the fuse can be relatively unlimited.

When the VT fuse was used with such outstanding

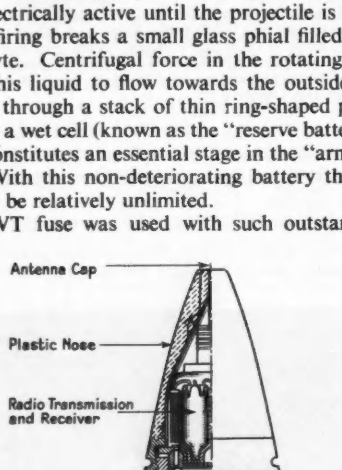


FIG. 18.—Diagram showing the position of the radio-proximity fuse in a shell. The diagram is based on a U.S. Navy photograph.

success against large numbers of flying bombs a statistical comparison was made of its performance compared with other fuses. This conclusively established its value as hundreds per cent greater than the mechanical time fuse.* Since, on the downward trajectory, it will function on the radio echo from the ground, it has been used also very effectively in shore bombardment, exploding in the ideal position in the air over the heads of the defenders. And at sea it has brought about an unprecedented improvement in the success of AA gunnery.

Both for directing offensive raids and for intercepting hostile raids radar has become a vital feature of naval air operations. But it will be realised that the adaptation of airborne R.A.F. sets for Fleet Air Arm purposes proved no easy task, remembering the limits to the weight and size of equipment fitted in an aircraft which must land and take-off on the short length of a carrier's flight deck. Remember, too, that many naval aircraft have folding wings. But radar installations in naval aircraft have always kept pace with modern developments. Their ASV sets have enabled them to track down U-boats and to make effective strikes on enemy shipping. In the latter task the epic performance of two land-based naval air squadrons operating from Malta in 1941 was an outstanding example of the value of ASV radar. Enemy air activity over the Mediterranean was so intensive that it was fatal for our ancient Swordfish to make daylight sweeps against the continuous stream of enemy shipping feeding Rommel's armies in North Africa. And due to the extra weight of the radar equipment it was impossible for those aircraft to carry both radar and torpedo for night sweeps. To overcome this handicap one aircraft of another squadron was fitted with radar and acted as a guide, bringing in the torpedo aircraft when a quarry was

* The official U.S. report quotes a success 4–5 times as great as that with other fuses—ED.

sighted. By this means they built up a menace to Rommel's supplies out of all proportion to their strength. This small force of obsolete Swordfish became a major reason why the Axis wanted us off Malta, and the enemy's intensive bombing of the island was a measure of his appreciation of the effectiveness of the primitive ASV sets.

The technique of fighter direction from aircraft carriers has been intensively developed, and in some operations special ships have been fitted with elaborate apparatus intended exclusively for the control of fighter aircraft. The patrolling fighters are constantly followed on the "Skiatron" screen of the carrier's air-warning radar. When hostile aircraft (showing no IFF response) are plotted on the same screen the number of possible interceptions can be quickly computed, and directions passed to our pilots for their correct intercepting courses. Following these directions they eventually pick up their respective quarries on their AI radar. Meanwhile, other fighters are being flown off the flight deck and vectored into position to provide a second screen, while the gunnery radar sets are preparing to deal with any raiders which may slip through. Finally, after an attack is beaten off the scattered fighters "call up" the mother-ship on their Interrogator. The radar beacon in the carrier is triggered and sends out its "signature" which gives them accurate information of distance and guides them back.

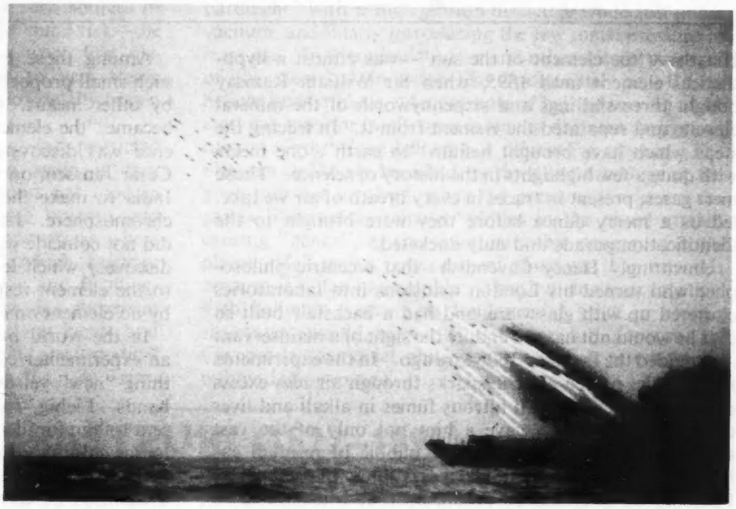


FIG. 19.—A landing craft has fired two "ripples" of rockets.

A striking instance of the effect of radar on naval policy arose in the development of the rocket-firing landing craft for beach bombardment. When the use of rockets for augmenting the fire power of our invasion forces was being considered it appeared at first that only ten rocket projectors could be fitted in an LCT (Fig. 19). Each projector would require a gun crew of six for laying, training, loading and supply of ammunition. They would then be able to fire single rounds in slow time while cruising in a vulnerable position off the enemy beach. An alternative proposal was that the deck should be fitted with projectors stacked as close as practicable, all fixed in elevation and training for firing a salvo of unprecedented magnitude on a quick run in and out. But this entailed positioning the craft very accurately at the firing-point, possibly in dim light and in a smoke-screen. No naval radar set was available that was sufficiently light and small for fitting in an LCT to give the necessary positional accuracy. But aircraft H2S sets were adapted and fitted. These gave, on their PPI display, an outline of the enemy coast and provided perfect blind ranging. So that on D-Day, a single firing number in each LCT(R) threw a switch that sent a rippled salvo of about 1,000 HE rockets to "neutralise" the beaches ahead of our landing infantry.

The use of aids similar to those for aircraft has solved the age-old problem of perfectly accurate navigation for the mariner at sea. In the summer of 1942 the Navy began to install Gee in light coastal craft and by using facilities offered by the Southern Gee Chain they were able to navigate accurately in all weathers in the English Channel. Since then naval vessels have been fitted in ever increasing numbers and the use of Gee has been found of inestimable help in many directions, e.g. it enabled minesweepers to sweep definite lanes with precision. The use of long range navigational aids, and radar detection of hazards for pilotage in dangerous waters will be among the major applications of radar in peace-time.

(To be concluded)

PROGRESS OF SCIENCE—*continued from p. 362*

expected, the Germans did their best to jam the radio links of our aircraft with their bases, and to upset radio navigation aids and, to cope with this situation, scientists flew on combat missions to study methods for overcoming the jamming: it is recorded that one scientist lost his life on such a mission during the Arnhem operations. The scientist was Dr. C. A. Wingfield, a promising biologist in his early thirties.

When the flying bombs began to be used difficulty was found by interceptor pilots in estimating their speed and range at night from the glow of light emitted by the propulsive jets, but scientific studies quickly led to the application of radar aids to the destruction of these weapons.

Perhaps the greatest asset which the scientists had in teaching R.A.F. personnel how to improve their efficiency by scientific methods was the fact that the crews knew that the scientists had actual combat experience and were not merely arm-chair critics. The result was to inspire respect for their opinions and to promote an atmosphere of co-operation with the aircrews.

Fifty Years of Helium

HELIUM—"the element of the sun"—was almost a hypothetical element until 1895, when Sir William Ramsay bought three shillings and sixpennyworth of the mineral cleveite and separated the element from it. In tracing the steps which have brought helium "to earth", one meets with quite a few highlights in the history of science. Those inert gases, present in traces in every breath of air we take, led us a merry dance before they were brought to the identification parade and duly docketed.

Unwittingly Henry Cavendish—that eccentric philosopher who turned his London mansions into laboratories cluttered up with glassware, and had a backstair built so that he would not have to endure the sight of a maidservant —provided the first step 160 years ago. In the experiments in which he passed electric sparks through air *plus* excess oxygen and absorbed all nitrous fumes in alkali and liver of potash, Cavendish gave a hint not only of the vast synthetic nitrogen industry. The bubble of residual gas in his tube was to prove, 150 years later, the bubble of Fortune, for it contained argon, neon and helium, to be used for electric lamps and those signs which on pre-war nights beckoned so brightly from the door of every tavern. Cavendish could naturally do nothing with this bubble: he would have been surprised at its contents, as he would have been surprised at the utility of the constituent gases.

Rayleigh and Ramsay

For over 100 years the Cavendish experiment was ignored or forgotten. Then, in 1893, Lord Rayleigh described before the Royal Society how he had found one litre of nitrogen from air to weigh a definite fraction more than a litre prepared from nitrogen compounds. He invited suggestions from chemists to explain this phenomenon: but, as with the Cavendish experiment, there was no reply, no one eager to take up the pursuit. So Rayleigh, in a dairy on his estate, repeated the Cavendish experiment on a large scale. Vessels intended to be filled with cream held caustic soda; a telephone rigged up near his apparatus and connected to his library (while an electric arc passed through air in his glass vessel) told him that the arc was still functioning, that throughout long hours the fixation of nitrogen was progressing while he dozed. Thus did Rayleigh entrap an inert gas or a mixture of such gases, gases which are egoists among chemical elements, drones which form no compounds or associations with others. Since the gas came from air Rayleigh would have called it "aeron". But growing tired of the disbelievers, the jesting sceptics who hinted at Aaron by asking him when Moses would arrive, Rayleigh finally named it "argon" from the Greek signifying "idle" ("the labourers from the vineyard stood idle in the market place" was what Rayleigh had been reading in his Greek testament). Cavendish's magic bubble also contained other drones, later to be enlisted in man's service. A contemporary of Rayleigh, namely Ramsay, a chemist, obtained his inert gas residue by making use of the ability of nitrogen to combine with red-hot magnesium forming the nitride, the inert gases passing unchanged along the tube. Rayleigh and Ramsay jointly announced their results at the Oxford meeting of the British Association in 1894.

Among those inert gases helium was hiding, but in such small proportion that helium was identified and won by other means. First must be mentioned how helium became "the element of the sun" before an earthly existence was discovered. It was in 1868 that Pierre Jules César Janssen, on the occasion of a total eclipse, went to India to make the first spectroscopic study of the sun's chromosphere. Janssen noticed a yellow line, D_3, which did not coincide with the line from sodium. This was the discovery which led Lockyer to give the name "helium" to the element responsible, since the line was represented by no element on earth.

In the world of chemistry it sometimes happens that an experimenter comes so very near to discovering something "new" yet misses the vital clue when almost in his hands. Liebig, for example, had a sample of bromine sent to him for identification, but he ignored it as probably iodine chloride. When Balard announced his discovery of bromine, Liebig must metaphorically have kicked himself; afterwards he certainly put a sample of bromine in his special cabinet called his "cupboard of mistakes". Hillebrand's reaction must have been similar when round about 1890 he treated the mineral uraninite with dilute acid, noticed an inactive gas involved, thought it to be nitrogen, and never explored further. Ramsay, reading of this experiment, was not satisfied. Repeating it with his cleveite, he obtained a little nitrogen *plus* argon together with yet another gas which he sent to Lockyer and Crookes for examination since he himself lacked a spectroscope of sufficient high power for use. Lockyer was soon singing the praises of the "glorious yellow effulgence of the capillary tube" on seeing the effect of passing a high-tension discharge through that tube invented by Geissler, a glass-blower. Ramsay thought the gas might be "krypton", an element which should accompany argon, an element hidden as a cryptogram. But soon Rayleigh was eulogising to his wife "the magnificent yellow line, brilliantly bright, not coincident with, but very close to the sodium yellow line". Soon, too, he was telegraphing to Berthelot: *Gas obtenu par moi clevite mélange A et He. Crookes identifie spectre. Faites communication Académie lundi* . . . RAMSAY.

Yet Per Theodor Cleve, the Swedish chemist and professor at Upsala whose name is perpetuated in cleveite, must be allowed to share in the honour attached to the discovery of helium. For Cleve, and his student Langlet, seem to have obtained a purer sample of helium and a more accurate value for its atomic weight than did Ramsay.

After fifty years helium is just as absorbing a subject as ever. It is produced from air as a by-product from oxygen manufacture, the helium-neon fraction from liquid air being first separated. A second source (by far the largest) is from natural gas of petroleum wells. At a time when Eckener and the other airship enthusiasts who continued the work of Count Zeppelin were searching for large supplies, helium became available from Canadian and American wells; the hydrocarbons in the natural gas were liquefied and the helium separated by fractional distillation. There is a potential source in those *soffioni* or volcanic steam jets of Tuscany. These are now called

soffionissimi owing to the much greater pressures involved since Italian engineers began to bore for such sources of power, then fixing a steel casing head (at some risk—the *soffioni* at Lardarello roared for a week when first disturbed), and so obtaining, in addition to vast steam power, boric acid, ammonia, carbon dioxide, hydrogen and helium.

An industry which the war-time black-out restricted but which will soon be in full swing again is that producing electric signs. Neon is the inert gas used in most cases for advertisements, aerodrome beacons and harbour lights; helium is adopted in other cases where bright yellow—the "yellow effulgence" which Lockyer admired—is required in signs. In London and Birmingham factories it is interesting to watch the sign-makers at work, expert glass-blowers shaping the long bends and tracks of wide glass tubing with such mathematical precision of curve and angle, fusing on the side arms, evacuating completely the finished tube followed by "bombardment" with a high tension discharge while still under vacuum, and finally introducing the few mms. pressure of inert gas. In thermionic valves and other special products of the electrical industry like "pointolite" arc lamps, helium finds a place. An example of helium serving as an inert gas superior to nitrogen is seen in deep-sea diving and caisson work, where helium is a diluent for oxygen. The nitrogen in the air breathed by the diver dissolves at the great pressure involved; when the pressure is released the gas is liberated as minute bubbles in the blood stream causing "bends", as the diver calls this dangerous complaint. Helium is a better diluent of oxygen than nitrogen because it is far less soluble. This humane use, together with helium's position as fundamental brick in atomic structures, would have met with the full approval of Cavendish, that quiet philosopher who first saw a magic bubble 160 years ago.

M. SCHOFIELD, M.A., F.R.I.C.

LOUIS PASTEUR (1822–1895)

IT is just fifty years since Louis Pasteur died at the age of 73 at St. Cloud, and just sixty since he reached one of the highest scientific peaks in a career of such distinction that T. H. Huxley could estimate that the monetary value of Pasteur's work more than compensated France for the cost of the Franco-Prussian war. It was early in July 1885 that three Alsatians came to the laboratory of Pasteur: two days earlier Theodore Vone, a grocer, had been attacked by a mad dog, but not bitten, while Joseph Meister, a child of nine had been severely bitten by the same dog. Vone and the child's mother brought him to Pasteur in an attempt to save the boy from infection by the rabies from which the dog was suffering. Pasteur had been engaged on these researches for some years. Five years before he had been called in to deal with an epidemic of chicken cholera, a disease which had killed off 10 per cent of the fowls in France, and he had succeeded in curing it by isolating the germ and culturing an attenuated form of it which, when injected, caused a mild form of the disease and conferred immunity against the virulent form. He had then repeated the same technique in dealing with the cattle-killing disease, anthrax, whose natural history he had investigated in the years 1877-9.

In his studies of rabies he had drawn on these earlier experiences. He found that the virus was present in the spinal cord of rabbits infected with it, and further, that short lengths of cord gradually lost their virulence when kept under suitable conditions. In a long series of experiments he obtained, by passing the disease from rabbit to rabbit, a virus requiring seven days for its incubation, and it was this form which he used in his treatment of the disease. In his experiments on rabbits he used extracts of sections of spinal cord from infected rabbits which had been kept for various periods of time. His technique was to inject a rabbit, first with the extract from a section of cord which had been kept for a fortnight or more, and then, on successive days, with newer and still newer extracts that were consequently more and more virulent. By the time the course was finished the rabbit had an immunity even to a direct injection into the brain with a virulent culture of the disease.

When the injured boy was brought to him he consulted two other physicians and then, for the first time, tried out his technique on a living person, arguing that the boy was almost certain to contract the disease if left untreated. The patient recovered, and at the end of October 1885 Pasteur described the results of his work to scientific audiences, adding yet another laurel to his crown.

The work which Pasteur accomplished in his lifetime is of an almost incredible extent, all of it revealing a genius for selecting for study problems of direct practical value which were yet of the greatest fundamental importance. His earliest work led to the discovery that molecules of complex substances can often exist in two distinct forms having the same chemical formula though the atoms in the two molecules are arranged in such a way that one is the mirror image of the other. His first great piece of industrial research was concerned with the souring of beers and wines, which led him to his classic studies on fermentation, its attribution to the action of micro-organisms, the proof that these were not the result of spontaneous generation as had been thought, the foundation of the germ theory of disease and its important consequence of the development of antiseptic and aseptic surgery.

As if this were not enough for one man, he next turned his attention to the silkworm disease which was ravaging the French industry, and not only did he isolate two strains of bacilli responsible but he also devised methods for preventing the contagion. This work certainly saved the French silk industry. What is even more remarkable is that his further work on fermentation, on chicken cholera, anthrax and rabies, was all done after he had become the victim in 1868 of a disorder which left him partly paralysed.

It is given to few men to make even one crucial discovery in science and the long chain of classic researches carried out by Pasteur parallels that of Rutherford and his school in the field of physics. In Pasteur we see the the proof that the world, in spite of war and destruction, is still on its road of advancement, and that, even more than the commercial value of his services to his country, the legacy of scientific tradition which he left to France still remains half a century after his death as an earnest of the future of France, reborn from disaster.

Supercharging the Nucleus

THE STORY OF COLCHICINE AND ARTIFICIAL POLYPLOIDS

P. T. THOMAS, Ph.D.

ALL plants and animals develop from single cells which, in most organisms, are the fertilised eggs. Growth is by the successive division of these cells resulting in a progressive increase in their number. Thus we find that the adult organism is usually a complex aggregation of millions of cells. During development they become variously modified in shape and structure according to the special functions they have to perform in the different tissues of the organism. For example, cells in the roots of a plant are concerned with the intake of water and mineral nutrients while cells in the leaf are specially adapted for the synthesis of carbohydrates from the carbon dioxide in the atmosphere.

Cell division and cell differentiation are two fundamental life processes, the understanding and control of which have far-reaching implications. In fact it is true to say that just as the study of the atom has directed the progress of chemical and physical science, so the study of the cell is now leading to important advances in biology, medicine and agriculture.

The central governing body in the living cell is the nucleus which immediately before cell division resolves into rod-shaped elements called chromosomes (Fig. 1). In nearly all plants the male and female germ cells contribute the same number of chromosomes to the fertilised egg, and in the species which are the simplest from the point of view of heredity each chromosome from the pollen has *one* corresponding partner in the female germ cell. Such plants with two corresponding sets of chromosomes we term *diploids*. Fig. 1 illustrates the chromosomes from a diploid species of *Trillium* and you will observe that they can be arranged in pairs according to their size and shape; one of the *A* chromosomes has been derived from the egg and the other from the pollen grain; the same thing happened with the chromosomes labelled *B*, and so on.

This is precisely the way in which the active units of inheritance, called genes, are transmitted from parent to offspring—they are carried by the chromosomes. These genes are responsible for the hereditary characteristics of a plant such as time of maturity, yield, habit of growth, disease resistance, colour of flower and fruit and indeed everything in its nature that makes it what it is. The corresponding chromosomes each carry a set of genes which are concerned with the same characteristics. This means that the plant is governed by the combined action of an equal number of genes derived from its two parents.

Now these chromosomes also control the process of cell division during growth in such a way that each daughter cell receives the same complement of chromosomes as the original fertilised egg. Thus, while different organisms vary in the number and type of chromosomes, since they carry different genes, each body cell of a particular species usually has the same number. For example, every body cell of a raspberry has 14 chromosomes (two sets of 7), a cabbage 18, a turnip 20, a horse 78 and man 48.

During mitosis, as we call the process of nuclear and cell reproduction, the chromosomes divide along their length into two identical halves, and then arrange themselves in one plane to form a flat plate across the cell. This is the stage illustrated in Fig. 1; this arrangement would be seen under the microscope if you were looking at it from one end of the cell. (Figs. 2-5, on the other hand, show cells in side view.) The daughter chromosomes next move to opposite ends of the cell, as in Fig. 2. A partition or wall now develops between these two identical groups of chromosomes, thus forming two daughter cells which are similar in every way to the original parent cell.

These purely mechanical aspects of mitosis had long been known. But recent advances have made it possible for us to understand more clearly not only how the cell works but also how changes within it result in abnormal growth. We are now finding that normal growth actually involves a complicated chain of physico-chemical events which go on within the cell with miraculous precision. Moreover, it is possible to identify the main links in the chain and to relate any departure from normal behaviour to a particular link.

Evidence is accumulating, for example, to support the view that one of the main factors for normal growth is the supply of nucleic acid in the cell—chromosome reproduction and protein synthesis being dependent on this substance.* If the supply of nucleic acid is deficient the rate of cell division is retarded and growth may even stop. When, on the other hand, the supply is excessive the rate of mitosis is correspondingly increased to such an extent that the growth becomes uncontrolled or malignant. In other words normal, or controlled, growth depends on

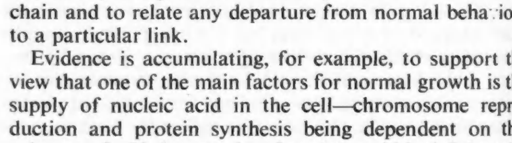


FIG. 1.—These are the five pairs of chromosomes in the ordinary diploid cell of *Trillium* (a member of the Lily family). *Preparation and photograph by S. H. Revell*

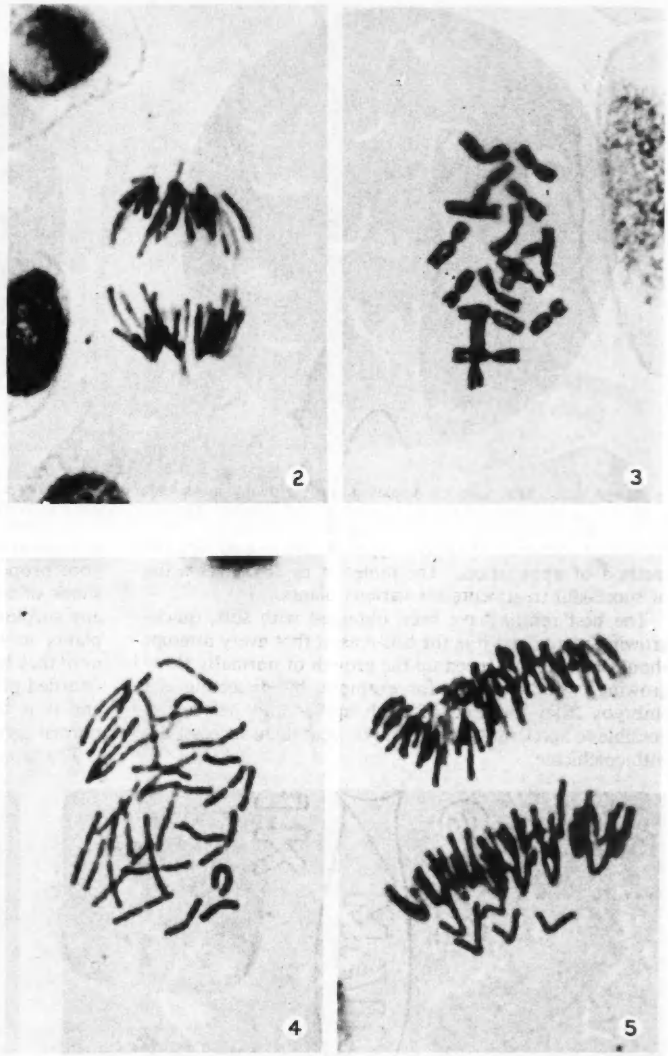
*For further information on this point, see Dr. C. D. Darlington's article "The Chemical Basis of Heredity and Development," DISCOVERY, March 1945, p. 79.

the correct amount of nucleic acid for chromosome reproduction.

The events within the cell are so co-ordinated that an upset in any single factor will alter the delicate balance which obtains normally. Thus in malignant tumours there is an accumulation of lactic acid within the cells, and recent work on the action of this acid on dividing plant cells suggests that it may be responsible for the degenerative phase in tumours. It upsets mitosis by interfering with the regular distribution of chromosomes to the daughter cells. Consequently there is a range in chromosome number in the different cells just as we find in the later stages of tumour development.

Now this kind of work has led not only to our better understanding of the process of cell division but also to the discovery of methods for controlling it. While the search for chemicals which would arrest the growth of tumours has so far only been partially successful it has led to the discovery of substances which can control cell division in plants in a way which regularly alters the number of chromosomes.

One of these substances, whose action was first observed by Dustin and Lits at the Medical School in Brussels, is colchicine. This is a poisonous alkaloid which is extracted from the Autumn Crocus (*Colchicum autumnale*) and has been used in medicine for the treatment of gout. Figs. 3-5 illustrate the action of this drug on the chromosomes during mitosis. It acts by preventing the normal regular orientation of the chromosomes on a flat plate across the cell which was seen in Fig. 1; instead the chromosomes become distributed at random throughout the cell, as shown in Fig. 3. The daughter chromosomes divide and separate normally (Fig. 4), but since they are not orientated properly they separate in odd directions and fail to form two compact groups as in Fig. 2. Under these conditions, no cell wall is formed to produce two cells so that we now have one cell with twice the number of chromosomes. By carefully regulating the application of the drug so that this duplication of the chromosomes occurs only once for every cell it is possible to produce plants on which all the cells have twice the chromosome number. Plants with double the number of chromosomes (*polyploids*, as they are called) were first successfully induced by several American geneticists working independently. Since then the technique of application has been improved and new active drugs discovered with the result that polyploids can be produced from almost any plant.



FIGS. 2-5.—The first of these four photographs shows the end of normal mitosis (ordinary nuclear division) in the onion; the 16 daughter chromosomes are moving towards opposite poles.

FIGS. 3 and 4 show what happens when colchicine is applied. Observe in both photographs that the orderly arrangement is upset and although each chromosome divides into two, the two daughter chromosomes fail to move towards opposite poles. Thus, in Fig. 4, the chromosomes are seen to be distributed at random; there is one large aggregate instead of two separate groups.
After the drug is removed, the plant reverts to the normal method of nuclear division; the two groups in Fig. 5 each come to contain 32 chromosomes instead of 16—contrast Fig. 2.

Method of Drug application.—In general it is not difficult to apply colchicine successfully to induce chromosome duplication in plants. The aim is to subject those cells in the region of the growing-point to the action of the drug. This is usually done by immersing germinating seeds, growing embryos or shoots in a weak aqueous solution of the drug, or again by adding drops to the growing point of young seedlings or actively growing shoots (Figs. 6, 7). When the growing-point is so well protected that the drug cannot easily reach the innermost cells, careful injection with a hypodermic needle is sometimes effective (Fig. 8). Strength of solution and duration of

FIG. 6.—(*A*) Apple embryos growing in water and (*B*) in 0.05 per cent colchicine solution. Note the bulbous roots of the treated embryos.

treatment depends both on type of plant and on the method of application. The table on p. 381 gives a list of successful treatments for various plants.

The best results have been obtained with soft, quick-growing plants and it is for this reason that every attempt should be made to speed up the growth of normally slow-growing, woody plants: for example, by dissecting the embryos from the seed of fresh apples and pears it is possible to accelerate growth and to treat them successfully with colchicine.

Even after the optimum dosage has been discovered, a good proportion of the plants will fail to recover from the shock of treatment. It is necessary, therefore, to remove any surplus drug by washing with water and to keep the plants in the shade under relatively humid conditions until they begin to grow. Actually it is the worst and most retarded plants that are more likely to become polyploids and it is these that should be carefully nursed back to normal growth (Fig. 7).

The appearance of bulbous swellings on the roots

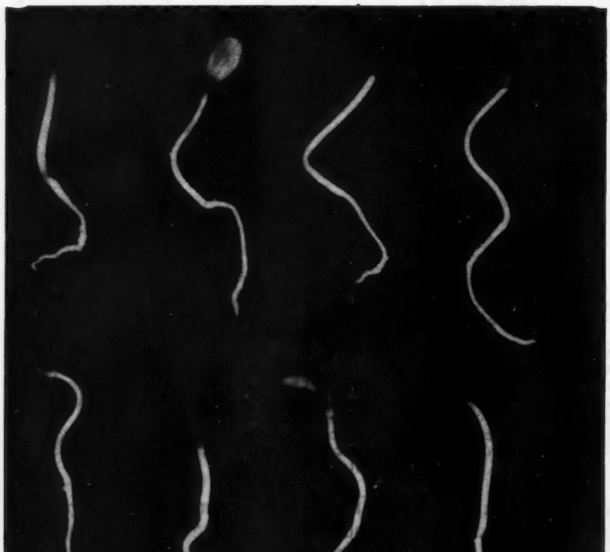


FIG. 7.—The embryos of Fig. 6 ten days later. (*A*) untreated, (*B*) treated. In practice, stunted seedlings such as X are selected, stunting being a sign that treatment has been effective.

(Figs. 6, 7), a thickening of the stems followed by the development of thick, distorted and dark green leaves are early signs that the treatment has been effective. At a later stage the increased size of the leaf stomata is a good criterion of polyploidy. But probably the most reliable criterion short of counting the chromosomes is to compare the pollen grains. Fig. 10 shows the pollen grains from the tetraploid and diploid plants of Petunia illustrated in Fig. 9. Note that the pollen from the tetraploid is not only larger than from the diploid but a proportion of the grains have four germ pores instead of the usual three. This difference in the number of germ pores is very common.

From comparison of Figs. 2 and 5 you will observe that the polyploid cell has over twice the volume of the diploid cell. This means that, with the same rate of cell division, we can also expect the whole plant to be larger. In general we find this to be the case. Polyploid plants are typically more robust; they have stouter stems, thicker and broader leaves and, in particular, the flowers and fruits are usually larger (Fig. 12). A variety of pear called Seabrook's Improved Fertility (Fig. 13) is an example of a tetraploid which has fruits about twice the size of the normal pear from which it arose by chromosome duplication.

At the same time the range of variation is extended and the polyploids may have such characteristics as increased resistance to frost and other adverse conditions, or may give rise to new shades of flower colour.

It is important to realise, however, that all plants cannot benefit by polyploidy. There

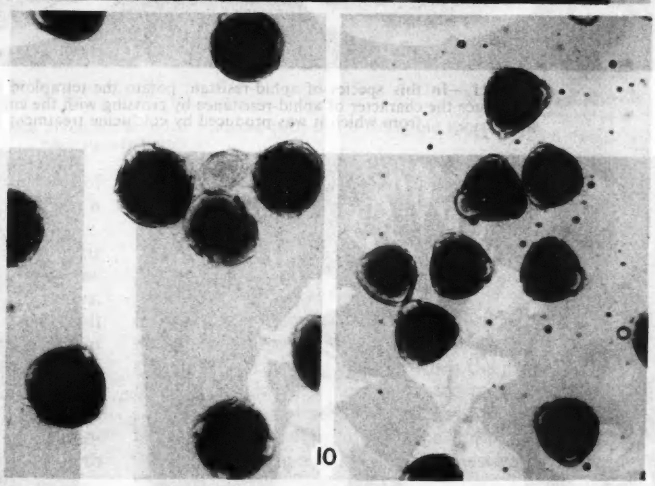


FIG. 8 (*left*).—Application of drops of colchicine solution to the growing-point of young radish seedlings.

FIG. 9 (*above*).—A tetraploid petunia (*left*) produced by colchicine treatment, with the diploid plant alongside. In Fig. 10 are seen the pollen grains corresponding to each plant; note the difference in size and shape.

are several reasons for this. Firstly, induced polyploids from fertile plants tend to be seed sterile on account of difficulties in chromosome assortment at germ cell formation. This is a disadvantage in plants where the seed is the economic product, as in barley, or where seeds are necessary for propagation as in the tomato. The degree of fertility can be raised by selection, however.

Failure occurs with some plants such as the potato, banana, tea, pineapple, tulips and ornamental flowering cherries because they are polyploids already, and a further increase in chromosome number leads to no improvement. In these types of plants, sterility is often a decided advantage. The cultivated seedless banana, where its wild

FIG. 11.—In this species of aphid-resistant potato the tetraploid (*right*) has been produced in order to introduce the character of aphid-resistance by crossing with the cultivated potato. The diploid type (*left*) from which it was produced by colchicine treatment is much smaller in habit.

FIG. 12.—Radish flower heads illustrate the difference between diploid and tetraploid; the tetraploid on the left has larger flowers and thicker stems.

FIG. 13.—The photograph shows the size difference between a diploid (*left*) and a tetraploid sport of the pear variety Fertility.

diploid ancestor contains hard seeds about the size of cherry stones, is one instance. The tea plant where a vigorous fleshy young shoot is required is another instance.

These polyploids arose spontaneously during their period of evolution extending over a long period of time and man, seeing that they were better than their relatives, selected them and brought them into cultivation. Now it often happens that there are diploid plants in the wild that possess certain desirable characteristics not present in the cultivated polyploid relative. For example, there are diploid species of potato in the wild which are resistant to virus disease. Since they contain only half the chromosome number of the cultivated potato it has not hitherto been possible to breed new and improved types from crosses between the two forms. But now that we can induce tetraploid forms of these wild species at will it is possible to produce new types of cultivated potatoes which will

Plant	*Method of treatment*	*Strength of solution*	*Time of application*
Cotton	Seeds Buds	0·05—0·1%	12—24 hrs.
Datura	Seeds	0·2—1·6%	12—24 hrs.
Barley	Seeds	0·06%	48 hrs.
Radish	Seeds	0·05%	48 hrs.
Apples Pears	Embryos from fresh seeds	0·05%	48 hrs.
Lilium	Young flowering stalk —immersed	0·2—1%	2 hrs.
Beans (dwarf)	Seedlings—drops added to growing point	0·05%	Twice a day for 3 days.

Table giving details of colchicine application.

contain this desirable character of resistance to disease. Fig. 11 illustrates the wild diploid (left) and an induced tetraploid form (right) of a species of potato which repels aphids (a carrier of virus disease). This new form is now being crossed with the cultivated potato in order to breed healthier varieties.

It often happens that a plant breeder fails to combine good characters from two plant types because the cross or hybrid is sterile. This occurs when the parents are distant relatives such as, for example, the pear and a quince or the peach and almond. Sterile hybrids of this kind can be made fertile by chromosome duplication, and this is where colchicine will be of the greatest value. We already knew that a number of economic plants arose naturally as hybrid polyploids. For example, the loganberry is a fertile polyploid hybrid between a raspberry and a blackberry, the ordinary hybrid between these two relatives being quite sterile. Similarly, the swede arose as a polyploid hybrid between the turnip and a cabbage. Other examples of hybrid polyploids are wheat, oats and strawberry.

It now means that with the aid of drugs such as colchicine the plant breeder will be able to produce at will all manner of new plants of this kind without having to wait for them to arise spontaneously at intervals of perhaps hundreds of years. The next ten years should see tremendous strides in the improvement of flowers and vegetables, while in only a few decades it will be possible, given proper facilities, to change our stocks of fruit trees and even forest trees beyond any previous expectations. The quickest advance will be made if the drug, which is very scarce, is used under the supervision of plant-improvement specialists; this is necessary because it is essential to understand the chomosome constitution of

a particular plant before deciding whether it is likely to benefit from chromosome duplication.

The history of the artificial induction of polyploidy is but one example of how fundamental research can lead to advances of real practical value. Very often when a certain problem dealing with fundamental life processes is undertaken it is not possible to predict who will immediately benefit—it may be the researcher worker investigating cancer, or it may even be a breeder of farm animals. But past history assures that the ultimate benefit will be for all.

TALKING BOOKS FOR THE BLIND

THE Technical Research Committee of the National Institute for the Blind, from 1920 onwards, investigated many different methods for recording sound, with the object of finding some system whereby the blind, particularly those unable to master Braille or other finger-reading —a considerable proportion of the blind population—could "read" by listening to the spoken word reproduced.

Several devices were tested but were found to be impracticable or too expensive, and research was ultimately concentrated on two main systems: the gramophone disc and the film strip. In 1934 the Technical Research Committee decided to set up an experimental studio in London to expedite the study of both these methods and a Sound Recording Committee was appointed, under the chairmanship of Sir Ian Fraser, with St. Dunstan's offering to bear half the costs of the experimental work. Both the gramophone and film methods were found to be technically practicable, but the cost of the latter was high owing to the absence of commercial demand, whereas the manufacture of gramophone records was already a big industry. The gramophone method had the further merit that talking books of this type were already in use in the U.S.A., where the pioneer experiments in this field were undertaken by the American Foundation for the Blind, and it was obviously advantageous if books could be interchanged with the American libraries.

The chief technical problem encountered with the gramophone method was that a disc revolving at the standard speed of 78 revolutions per minute, could only reproduce a number of words equivalent to five or six minutes' reading time, and a whole book would therefore require a large number of discs, making it both expensive and cumbersome. The Sound Recording Committee, after prolonged experiments, produced a 12-in. solid-stock disc, cut at 200 grooves per inch, rotating at 24 r.p.m., thus giving 25 minutes' reading time on each side. The use of such a record meant that the reproducer for playing it would need a motor capable of steady operation at this slow speed, and a special light-weight pick-up to ensure that the fine record grooves were not damaged. Other difficulties, e.g., the search for a suitable needle and the designing of the equipment to make it easy of operation by the blind were successfully overcome, and the commercial gramophone companies agreed to process and press these special records.

The talking book scheme in its present form was inaugurated in 1936, and was of necessity launched on a limited scale, in view of the possibility of developments in the film tape or suitable methods of recording other than the disc. A limited number of machines was manufactured, and the Committee's policy was to sell them to the blind at production cost only, the prices ranging from about £6 10*s*. for electric models to about £4 for the spring motor and headphones type. Incidentally, all models can reproduce records at 24 r.p.m., American talking books at 33⅓ r.p.m., and normal records at 78 r.p.m. A book selection sub-committee was then appointed to advise on the best books for recording, and many tests were made at the studio to choose readers with the right type of voice and delivery, e.g., Grisewood and Hibberd, of the B.B.C.; few women's voices have been found suitable for this purpose. The Publishers' Association was also approached and permission was generously given to reproduce copyright works on payment of a nominal fee.

The talking books library has issued about 1,700 reproducers, and the majority of these are used by some 1,600 individual blind persons in their own homes, but many are installed in blind institutions. The Central Library has now available 464 books, comprising biography, fiction, travel, science, history, etc. The aim of the library is to provide entertainment and not, at the moment, to supply educational books and study courses. About half the titles were recorded in the Committee's own London studio, and the other half are recordings made in the U.S.A. and purchased by the Committee. The book selection committee tries to meet all tastes, although certain books that present technical or phonetic difficulties are not acceptable for recording, but, apart from these exceptions, no censorship or text-cutting is imposed on the blind reader as such.

Membership of this popular talking book library is free, and the only expense incurred by its members, after the initial purchase of a reproducer, is the payment of postage when returning the book containers, viz., 2½d. for maximum weight of 15 lb. at the Blind Literature postal rate. Outgoing postage on containers is paid by the Sound Recording Committee, who may also, at their discretion, help individual cases of financial hardship towards buying a reproducer. Three books at a time may be borrowed by members, and the reading time allowed is one month. 23,572 books were circulated in 1943, representing the despatch and receipt of 35,128 containers, holding on an average about 12 records each.

Unfortunately, the outbreak of war so soon after the inauguration of the scheme considerably curtailed its extension, particularly in the matter of manufacturing new reproducers, and there is now a long waiting list of blind persons anxious to acquire reproducers. Other war-time difficulties have been the shortage of components for servicing reproducers already distributed, and unavoidable delays in obtaining American talking books. Restrictions on record materials, labour, etc., have limited the number of new books recorded to twenty-five a year, and made it difficult to replace broken or worn records, but, on the whole, the library has maintained an adequate service during the war years, and many improvements and expansion of the service are anticipated with the return to normal conditions.

DONALD G. ALDOUS

The Bookshelf

Microbial Antagonisms and Antibiotic Substances. By S. A. Waksman. (The Commonwealth Fund, New York; pp. 350, 17 half-tone illustrations, 17 line drawings. British price, from Oxford University Press, 21*s*. 6*d*.).

Most workers in the field of antibiotics will be familiar with Professor Waksman's reviews of this subject in *Soil Science*, *Bacteriological Reviews*, and elsewhere. His approach is that of a soil microbiologist—a student of natural microbial populations rather than of the artificial cultures of pure strains which are the raw material of the research worker who confines his activities to the laboratory.

For many readers this book will be a valuable reminder that the study of antibiosis is something more than a search for new substances of value in chemotherapy. Important though they are in relation to medicine the antagonisms of micro-organisms play parts of the greatest economic importance in agriculture, industrial fermentation, and the food industry. Professor Waksman, with the skill of long practice, combines a survey of these wider aspects of his subject with the detailed account of specific antibiotics called for by the specialist. The book is therefore of considerable value to the latter though it is likely to find greatest favour with the non-specialist who requires a summary of modern knowledge of antibiotics but has neither time nor opportunity to search the extensive and scattered literature.

One of the most valuable features of the book is its bibliography of over a thousand references, though this includes no references later than the first part of 1944. The number of these dated in the later years of last century and the first quarter of the present one is a timely reminder that the study of microbial antagonisms did not begin with the discovery of penicillin in 1928.

One complete chapter is given to the chemistry of antibiotics, but the emphasis of the book as a whole is definitely biological.

As would be expected, much more space has been given to penicillin than to any other antibiotic. While much of the description of this substance is good it is rather surprising to find no account of its commercial production. The absence of any detailed chemical information on penicillin is accounted for by the secrecy regulations—astonishingly enough still in force—but the considerable data relating to the methods and scale of manufacture certainly deserve mention in a review of this kind.

A fact which the book makes very clear, although no particular attention is drawn to it, is the need for a thorough revision of the nomenclature of antibiotics. Many workers have given specific names of antibacterial metabolites before properly demonstrating that they are pure and have not previously been described. As a result several antibiotics, such as claviformin and helvolic acid, masquerade under several aliases, to the confusion of student and specialist alike.

As the most extensive review of antibiosis and antibiotics yet published Professor Waksman's book should be known to all interested in this subject. The student and those with wide interests will probably want to possess their own copy; the specialist, and especially the chemist, will probably find it sufficient to have a copy available for reference.

Trevor Williams

Structural Inorganic Chemistry. By A. F. Wells (Oxford University Press, London, 1945; pp. 590; 25*s*.).

The discovery of a new scientific tools such as X-ray crystallography releases a flood of books and articles concerned on the one hand with refinements in technique and on the other with reporting the results of its use in the study of hundreds of different materials. There comes a time when it is of great importance to systematise the new knowledge and to relate it to the main body of the subject. Two purposes are then served; first the achievements of the new tool can be fully appreciated by those unfamiliar with its technique, and secondly the gaps in its application to the subject as a whole are clearly revealed. Such gaps arise because the materials which are intrinsically easier or more interesting to study on technical grounds are not necessarily those of greatest general importance. In X-ray analysis, for example, far more attention has been paid to minerals than to the synthetic materials with which most inorganic chemists are concerned.

Dr. Wells's book, published on the eve of the 50th anniversary of the discovery of X-rays, admirably fulfils this need. He begins by relating the X-ray evidence to that obtained from other approaches to the problem of the nature of the chemical bond. This problem, which appears in various guises throughout the whole of modern chemistry, is to understand the nature of the forces which bind atoms together to form the materials of everyday life. Nearly every measurable physical property of solids, liquids and gases has been used at one time or another to help in its elucidation, but there is no doubt that X-ray crystallography, by revealing the ways in which atoms are arranged in space—the architecture of solids—has made possible enormous advances.

The main part of the book contains a comprehensive account of the structural chemistry of the solid compounds of hydrogen, the halogens, oxygen, sulphur, nitrogen, phosphorus, carbon, silicon and boron. Two final chapters deal with the special field of metals and alloys. The value of this part of the book to inorganic chemists is immense, and it has already found its way on to the shelves of many laboratory reference libraries. True, one is frequently disappointed at what appear to be omissions but, as a rule, these turn out to be due to gaps of the kind mentioned above rather than defects in the book itself.

The diagrams are on the whole clear and comprehensible, though greater use might perhaps have been made of photographs of models. A formula index is provided which, one hopes, will be revised and extended in later editions.

C. G. A. Hill

Far and Near

"Plan for Science" Committee

The Lord President of the Council has appointed a committee of leading scientists and others to consider policies for the use and development of Britain's scientific man-power and resources over the next 10 years. The committee consists of Sir Edward Appleton (secretary of D.S.I.R.), Sir Alan Barlow (Treasury), Professor P.M.S. Blackett, Mr. Geoffrey Crowther, Sir Alfred Egerton and Sir George Nelson.

Royal Society's New President

Sir Robert Robinson, who is internationally renowned for his brilliant contributions to organic chemistry, has been elected President of the Royal Society, in succession to Sir Henry Dale.

Director of Atomic Research Station

Professor J. D. Cockcroft has been appointed director of the Government's atomic research station (see last issue of Discovery, p. 352).

"L-Delays"

Mr. Herbert Morrison, Lord President of the Council, last month disclosed some details of the delayed-action fuse known as "L-Delay". The fuse is the size and shape of a fountain-pen, and about twice the weight. Inside is a striker, attached to a spring which in turn is attached to a small piece of black metal. The delayed action depends upon the time taken for the metal to break when stretched by the spring.

The idea was thought out by the Army, but everything depended on the "consistency" of the piece of metal, which had to have a uniform grain size throughout. This metallurgical problem was solved by the research association of the Non-Ferrous Metals Industry.

Very considerable accuracy was obtained. The fuse was timed to go off at times ranging from one hour to one month at normal temperatures. In the intense cold of the Russian winter, the time taken for the metal to break was much longer, while in hot countries such as Burma the time of the fuse was considerably reduced. The lead alloy metal unit, is 7/10ths of an inch long and 3/16ths of an inch in diameter. In the middle is a neck and it is this neck that

The John Innes Horticultural Institution has outgrown its grounds at Merton Park and is arranging to move to a new house—at Bayfordbury in Hertfordshire. The laboratories and offices will be housed in the mansion shown in the photograph; it was built in the eighteenth century with a publisher's profits from "Paradise Lost". The grounds cover 372 *acres and contain a valuable collection of trees established in* 1838.

breaks. The width of the neck had to be ground to an accuracy of 1/10,000th of an inch.

The fuse was used on every front during the war from 1941 onwards. It can be used either for explosives or incendiaries.

Research Association's Jubilee

THE British Non-Ferrous Medals Research Association celebrated its 25th anniversary last month. Officially incorporated in January 1920, it began with eighteen members and an annual income of less than £6,000. To-day membership exceeds 370 companies and the annual income is around £50,000. (About a third of this comes by D.S.I.R. grant). The Association's chairman for the period 1920-1937 was the late Mr. Thomas Bolton, who was succeeded by the present chairman, Sir John Greenly. The research department is headed by Mr. E. A. G. Liddiard, and Dr. A. G. Quarrell (senior metallurgist).

The Association has published a pleasing 47-page booklet to mark the occasion. Well illustrated and beautifully printed, it contains articles by Sir John Greenly, A. J. Murphy (on research policy), G. L. Bailey (organisation) and W. C. F. Hessenberg (review of current work and recent research results). Sir John Greenly mentions that it is proposed to increase the scale of the Association's activities, and to double its income.

Scientific Research and Industrial Planning

THE British Association's Division for Social and International Relations of Science held a conference on December 7 and 8 in London on the theme of "Scientific Research and Industrial Planning". We hope to be able to accommodate a report of the meeting in our next issue.

Films in German Schools

AN Educational Film Institute has been set up to organise the use of films in German schools. It will be concerned mainly with distribution and will work under the direct orders of the Control Commission.

Science for the Citizen

WE have received the following letter from a correspondent, Mr. J. L. Pinder, who follows up points made in the "Science for the Citizen" items in our October and November issues.

"They raise the wider issue of scientific programmes on the radio generally, a matter which received some consideration at the recent meeting of the London Section of the Royal Institute of Chemistry on 'The Publicity of Science'. The impression gained, both at that meeting and in private conversation afterwards, was that there was considerable room for improvement both in the quantity and average quality of programmes specifically devoted to scientific topics," Mr. Pinder writes.

"To a purely casual observer, the trouble seems to be an almost complete lack of recognition of the degree of integration necessary between science and the community, particularly so since the advent of the atomic bomb. The situation was bad enough before, although it is true that the percentage of time devoted to scientific and technical programmes has been increased slowly and grudgingly—largely as a result of the impact of the war—but now a community to whom a rational outlook on science and scientific achievement is a recognised cultural attribute may be one of the most potent safeguards against the abuse of atomic power. The radio is an obvious approach to such a community. This lack of appreciation of the role of science (from which arises the fact that, as far as the speaker from the B.B.C. could inform the meeting, there was, as yet, no B.B.C. Scientific Advisory Body) has led to the present patchiness of radio programmes and their lack of cohesion with one another. The excellence of the Feature Programmes produced by Nesta Pain and Cecil McGivern was widely acknowledged, but 'ScienceMagazine' came in for some criticism. The old Forces item 'Your heavy Questions Answered', which, both at the meeting and elsewhere, has been praised, is now only available on short-wave transmission, and, on being pressed for the reason for cutting out the medium-wave transmission of this programme, the B.B.C. speaker could give no answer whatever.

"A number of constructive proposals and comments were made at the meeting," continues Mr. Pinder. "It was evident that there was a general feeling that the sooner the B.B.C. appointed its Scientific Advisory Committee, the better. This, in the writer's opinion, should not be entirely *ad hoc*, but should have some linkage with recognised scientific bodies, particularly with those interested in the relationship of science and society, such as the British Association, the Parliamentary and Scientific Committee, the Association of Scientific Workers, and possibly bodies such as the Chemical Council."

Mr. Pinder asks for much greater co-ordination between the Directorates of Feature Programmes and Talks Programmes, and suggests more use could be made of postscripts to the 9 o'clock news for really up-to-the-minute topical talks. "Every issue of the *Radio Times* carries on its cover a summary of the more important programmes of the week, such as 'Plays', 'Variety', 'Music'. Is it not reasonable in this age to ask for the inclusion of 'Science', be the items contributed by 'Talks' or 'Features'?" he asks. "Every issue of the *Radio Times* contains 'Music Diary'. Why no 'Science Diary'?"

Finally Mr. Pinder suggests that there should be monthly or quarterly science supplements to the *Radio Times* or the *Listener*, when paper supply allows. These should contain verbatim reports of talks or reprints of scripts, which would be valuable for reference. He draws attention to the fact that sometimes one misses a programme and would welcome the opportunity of consulting a script of it in print; he quotes *Mulberry Harbour* as one he himself would like to read, and other readers besides Mr. Pinder will be interested to learn that the script of *The Harbour Called Mulberry* by Cecil McGivern (who is probably lost to radio now that he has joined the Rank film organisation) has been published by Pendulum Publications, price 2*s*.

We would point out that the radio programme "Your Questions Answered" can be heard on the Light Programme at 1.10 p.m. on Fridays.

RDX, Torpex and Tritonal

THE following comment appeared at the end of the article on cyclonite in a volume of *Thorpe's Dictionary of Applied Chemistry* published in 1939: *In spite of the difficulties indicated, the future of cyclonite as a major high explosive for military use is regarded as highly promising.* This prediction, coolly reflecting the pride of an explosives chemist in his craft, has come true during the war. Cyclonite, or RDX (Research Department Formula X) as it was labelled at Woolwich Arsenal, was made on a large scale in all the belligerent countries.

Under the name of "hexogen", cyclonite was first described in 1899 by G. F. Henning, who obtained a German patent for his method of preparing it by nitrating hexamine. This last-named substance is formed when ammonia is condensed with

Dr. C. F. Goodeve, first holder of the post of Deputy Controller for Research and Development at the Admiralty; now director of the steel industry's Research Association. Aged 41.

Mr. A. P. Rowe has succeeded Dr. Goodeve as Deputy Controller for Research and Development, Admiralty. Formerly head of the Telecommunications Research Establishment.

Dr. W. B. Lewis now directs the work of the Telecommunications Research Establishment. He has been connected at T.R.E. with several of the major radar developments of the war.

formaldehyde, but the new explosive received little attention until the commercial synthesis of methyl alcohol made available cheap supplies of formaldehyde. Cyclonite was first produced industrially (under the code name of T4) at an Italian plant owned by the Nobel Dynamite Company and located at Avigliana.

The reason for the slowness with which cyclonite was developed was that certain very unstable and explosive by-products rendered the nitration of hexamine extremely hazardous. The difficulty of making it on a scale that could be considered useful from the military point of view was solved in Britain a few years before the war by the Research Department at Woolwich Arsenal.

The explosive power of cyclonite lies in the fact that it is self-sufficient in oxygen—as can be gathered from a consideration of its formula, which is $(CH_2.N.NO_2)_3$—whereas TNT contains a relatively inadequate proportion of oxygen.

Thirty per cent of RDX coupled with 70 per cent of TNT gives an explosive mixture which can be poured or screw-filled into bombs and shells. Mixtures of this type have been used during the war.

Mixed with other ingredients RDX gave the "plastic explosive" so well known to British soldiers. This material has a consistency approaching that of plasticine and a stick of it can be wrapped around girders and similar structures which are cut by the explosion that occurs on detonation. As a Ministry of Information hand-out expresses it, the "plastic explosive" can be moulded to fit any complex-shaped structure which it is desired to destroy. Far more convenient to handle than gun cotton, it is, of course, more expensive to make than that explosive so often used in demolition charges.

By combining RDX, TNT and aluminium powder, an explosive mixture called "torpex" was developed to the production stage by Woolwich's Research Department. The addition of the aluminium powder speeds the rate of explosion by stepping up the temperature (which accelerates the chemical reactions involved in the explosion and also expands the gases produced). Torpex, officially described as "the most effective underwater explosive used during the war", replaced TNT in depth charges, mines and torpedoes with a great enhancement of the destructive effect of these weapons. It enabled the Allies to sink a larger number of enemy craft than would have been possible with the use of earlier types of explosives.

Another novel explosive which was used with outstanding success during the later stages of the war was tritonal. This consists of a mixture of TNT and aluminium powder. It gives more blast than TNT alone, and was used to fill many of the "block-busters" dropped by the R.A.F. and other bombs dropped by the U.S.A.A.F.

Books for Army Education

The Army Education Scheme has given rise to a demand for books, particularly technical books. These have been in demand by Army Units for many years but the demand has been stimulated by the increasing interest shown lately in education.

Most units have their own unit library, supplied either by voluntary gifts of books (normally these are of a very low standard), or else from a Central Command library which loans books out for a specified period. In addition, the majority of units receive a small monthly grant from the unit's funds for the purchase of new books. The choice of new books depends entirely upon the unit's Education Officer and the library committee.

Several correspondents have written complaining of their inability to obtain the necessary books with which to continue their studies. (More than one Service reader has sent money and requested us to order books.) These letters come mainly from correspondents serving overseas, and their grievance is aggravated by the fact that they normally have no access to civilian libraries. Home units usually have special facilities for obtaining books from the local and county libraries.

Although the Army Education Scheme provides for the issue of a library of about five hundred standard works to every unit, it seems doubtful if many of these libraries have yet been sent overseas or are readily available to isolated units. A general review of the Scheme seems to indicate that more attention is being paid to units stationed at home than to those serving abroad. If this is so, and there is a great deal of evidence pointing to the apathy of the authorities abroad, it is a pity, for units isolated from normal civilian life stand more in need of the successful implementation of the scheme than do the more fortunate ones stationed in this country.

Admittedly, books are scarce, and shipping is still limited. Such difficulties, however, are not insuperable, and a great deal could be done by a priority allocation of books to overseas Forces and a more generous grant from unit funds for the purchase of technical books. The interest in the Army Education Scheme is sufficient proof that many men and women in the Forces are genuinely attracted by education, either from a vocational or from a purely cultural point of view. It would be a pity if this new interest were allowed to dwindle through the lack of imagination on the part of those responsible for running the Scheme or through the inability to obtain the necessary books and material.

Sight and Sound on same Wavelength

An interesting development in television, which does away with the need for two separate wavelengths to transmit sound and vision, was recently announced by Pye Ltd. of Cambridge.

In ordinary television the picture is transmitted as a series of lines represented in Fig. 1(*a*) by AB, CD, EF, etc. These are traced out from left to right and successively from top to bottom of the picture. At the transmitting end, an electron beam scans the line AB, receiving a current varying with the brightness of the scene at each point of the line, and represented by the irregular curve AB of Fig. 1(*b*). This is used to modulate a radio-frequency carrier wave, as in

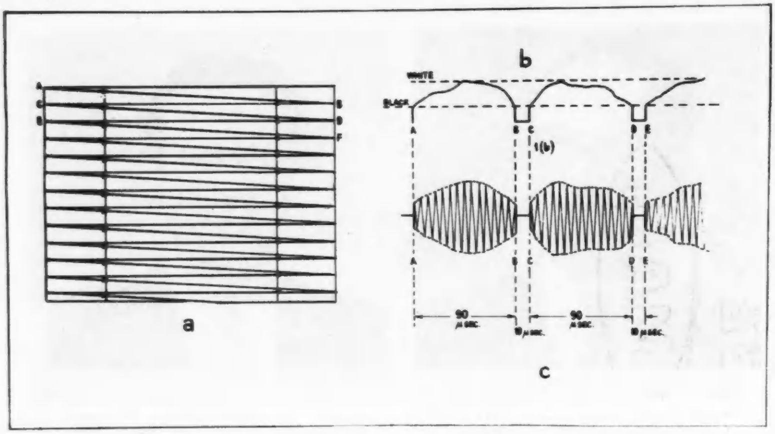


Fig. 1

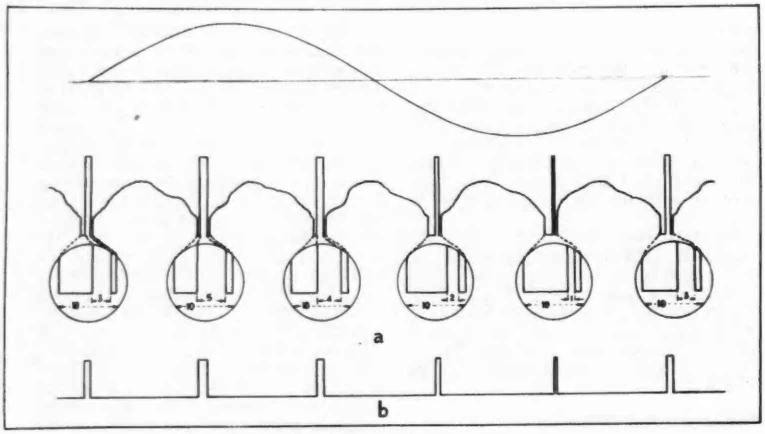


Fig. 2

Fig. 1(*c*), which is transmitted from the aerial. The receiver translates this modulated wave into the original variations in brightness, and traces them along a line corresponding to AB of Fig. 1(*a*). By a succession of such lines the picture is built up. The time taken on each line is 90 micro-seconds (a micro-second equals one-millionth of a second). After reaching B, the tracing beams at both transmitter and receiver must return to C before the next line can be transmitted. There is thus an interval of 10 micro-seconds during which nothing visible is being transmitted. At present standards of 405 lines per picture and 25 pictures per second, there are just over 10,000 of these "silent" intervals per second, which are only used as "synchronising signals" to make the tracing beam at the receiver keep step with that at the transmitter.

The essential point of the new system is to use these hitherto wasted intervals to transmit sound. The method of doing so can be understood by reference to Fig. 2(*a*). At the top of the figure is represented a sound wave. In each of the former wasted periods, the new system takes a "snapshot" of the sound waves and expresses this by varying the width of a radio pulse which is transmitted between the vision transmissions. The pulses are of constant height, but their width varies proportionally with the displacement of the sound waves. The receiver simply cuts off the tops of these pulses, as in Fig. 2(*b*), and reconverts them into sound waves.

The following advantages are claimed for the new system. It is freer from noise and interference than the pre-war method. It does away with the problem of separating the sound and vision signals at the receiver end and at the same time allows the receiver aerial to be more efficient, since it has only a single carrier frequency to deal with. It would save frequencies in the already overcrowded ether. The constant height of the pulses could be used for automatic volume control. The problems arising from interference of the former two transmitting aerials would disappear. The elimination of most of the separate sound receiver would reduce the cost of receivers by something like £2 per set—or £30 million if every radio licensee took up television, and this figure would represent a very considerable saving of man-power. As a possible future development, the height of the pulses might be varied to provide another signal controlling colour and thus give colour television.

Further advantages would follow if the pre-war 405-line system were replaced by one of 1000 lines. There would then be 25,000 pulses per second. These could be divided into two sets to transmit two sound programmes and thus give stereophonic sound. Alternatively, the greater frequency of pulses could be used to improve radically the quality of the sound. At present the sound frequency is limited to 5,000 cycles (all frequencies above 5,000 must be filtered off in order to prevent the inversion that would arise from beating with the constant pulse frequency of 10,000). This limit of 5,000 cycles corresponds roughly to present broadcasting standards, but an improvement would be welcome.

The idea of transmitting the sound in the intervals between the lines of the picture is not novel (see *Electronics*, 1941, Vol. 14, No. 5, p. 39, for an American scheme) but the use of a pulse of variable width as the means of sound transmission is new in this context, though it also was already known in a separate scheme. Most television receivers are combined with ordinary medium-wave or all-wave broadcast receivers which can be adapted for television sound, so that the saving in cost which can be realised in such cases is a highly debatable technical point. One thing, however, is certain: the limit of fidelity to an upper frequency of 5,000 cycles is typical of medium-wave broadcasting, but one of the great attractions of the pre-war television service was the higher quality of sound reproduction obtainable with the wider band of frequencies transmitted on the television service. The American scheme cited was with a 525 line picture, giving a maximum sound frequency of nearly 8,000 cycles, which is a more attractive proposition.

Personal Notes

Mr. E. F. Relf, C.B.E., F.R.S., F.R.Ae.S., has been appointed Principal of the College of Aeronautics. Since 1925 he has been Superintendent of the Aerodynamics Division of the National Physical Laboratory, Teddington.

The Minister of Education has appointed Dr. Herman Shaw, a Keeper in the Science Museum, to be Director of the Science Museum in succession to Col. Ernest Elliott Buckland Mackintosh, D.S.O., who retired on November 30.

Dr. H. Lipson is leaving the Cavendish Laboratory, Cambridge, to become head of the Department of Physics in the Manchester College of Technology, in succession to Dr. W. H. Taylor.

The Cover Picture

The Gloster Meteor jet-plane which set up the new speed record of 606·2 miles an hour on November 7. The plane, flown by Group Captain H. J. Wilson, was powered by two Rolls Derwent gas turbine engines.

Royal Society Medals

THE Royal Society has awarded Royal Medals to Professor J. D. BERNAL and DR. E. J. SALISBURY, director of the Royal Botanic Gardens, Kew. Professor Bernal's award is for his work on the structure of proteins and other substances by X-ray methods, and for the solution of many other problems requiring a physical approach. Dr. Salisbury is distinguished for his contributions to plant ecology and the study of the British flora.

The Royal Society's Copley Medal goes to DR. O. T. AVERY, of the Rockefeller Institute, New York, for his success in introducing chemical methods in the study of immunity against infective disease. PROFESSOR ROGER ADAMS, of the University of Illinois, gets a Davy Medal for his researches in organic chemistry and his recent work on alkaloids. The Hughes Medal is awarded to PROFESSOR B. F. J. SCHONLAND, director of the Bernard Price Institute of Geophysics in Witwatersrand University, for his work on atmospheric electricity and other researches.

More Nobel Prizes

Two Nobel Prizes for physics—for 1944 and 1945—were awarded last month, to Professor Otto Hahn and Professor Wolfgang Pauli. (It had been rumoured some time ago that Hahn was to receive a prize, and because of his work on the nuclear fission process in uranium and subsequent experiments which put the world on the road to the atomic bombs it became a current joke to inquire whether he would receive the Nobel prize for physics—or for peace!) The chemistry prize for 1945 has been given to PROFESSOR ARTTURI VIRTANEN.

Professor Hahn, who was born in 1879, has done a great deal of work in connection with radioactivity. In 1904-5 he worked in Ramsay's laboratory in London, and afterwards did research under Rutherford at Montreal. In 1906 he joined the staff of the Kaiser Wilhelm Institute for Chemistry, where he became professor in 1912. The discovery of mesothorium and protoactinium (in conjunction with Lise Meitner) stand to his credit and in 1938 he and Strassmann obtained experimental evidence of nuclear fission in uranium. Slow neutron bombardment of uranium gave a residue continuing barium and krypton, and this was followed up by intensive researches elsewhere. Hahn was last reported to be in the United States, though Swedish papers stick to their statement that that he is in Britain.

PAULI, an Austrian, contributed to sub-atomic physics the exclusion principle which concerns the distribution of electrons in orbits around the nucleus. According to the Pauli Exclusion Principle, no two electrons can have the same quantum numbers. (A simple explanation of the principle will be found in elementary books on sub-atomic physics, such as G. P. Thomson's *The Atom* in the Home University Library.) His studies of the small, temperature-independent paramagnetism exhibited by many metals led to his formulation, in 1927, of the electronic theory of metals. Pauli also

Professor A. I. Virtanen has won the Nobel Prize for his researches in the field of agricultural chemistry. His initials are associated with the name of a patent silage process.

hypothesised the existence of the neutrino, an uncharged atomic particle with the mass of an electron. At present he is in the United States, at Princeton University.

VIRTANEN, who is aged 50, is known for his agricultural researches. He devised the A.I.V. process of making silage. This technique was based on the observation that the lactic acid formed during ensilage exerts a preservative action on the fodder, and in the patented A.I.V. process a dilute solution of hydrochloric and sulphuric acids are added to hold in check further breakdown so reducing the loss of nutrients to a very low level. Professor Wirtanen was falsely reported killed during the war between Russia and Finland in 1940.

The prize for literature has gone to a Chiltern poet, Senorita Lucila Godoy y Alcayaga.

Obituaries

DR. F. W. ASTON, F.R.S. and Nobel Prizewinner (in chemistry) of 1922, died in Cambridge on November 20 at the age of 68. Educated at Malvern College and Birmingham University, his first university appointment was an assistant lecturer in physics at Birmingham in 1909. (He had by then already worked for three years as a research chemist in a brewery.) In 1910 he went to the Cavendish Laboratory to work under J. J. Thomson, and did research on various problems of vacuum discharges. Out of his work with Thomson on the analysis of positive rays by the "parabola" method grew the isotope researches for which Aston is renowned. He devised a gaseous diffusion method which confirmed the existence of two neon isotopes that had been indicated by the parabolas of neon.

For the period of the Great War Aston had to divert his attention to military problems; from 1914 to 1919 he was a technical assistant at the Royal Aircraft Establishment, one of the problems on which he then worked being concerned with finding suitable "dopes" for aeroplane fabric.

When he went back to Cambridge he began building a new positive-ray apparatus, able to measure atomic masses to one part in a thousand. He published the results of his mass spectographic measurements in 1920 and their acceptance led chemists to revise their approach to the whole system of atomic weights. Aston had established the existence of most of the isotopes of the permanent gases and of many elements that could be introduced into a gaseous discharge. The mass spectrograph with which he separated the isotopes depended for its action on the slight differences in behaviour of isotopes of slightly different mass moving in magnetic and electric fields. For a long time atomic weights were considered as begin exact whole numbers but Aston was able to show, using an improved mass spectrograph, that there was a definite discrepancy between fact and theory; for instance, lithium has two stable isotopes of masses 6.0167 and 7.0180 and the chlorine masses have masses 34.893 and 36.980. The masses were not whole numbers and the deviations from the whole number rule provided a vital clue for the research workers interested in the structure of the atomic nucleus.

His most important publication was his book *Mass Spectra and Isotopes*, a book which, incidentally, forms the best supplementary reading to the Smyth Report on the atomic bomb. (It is significant that a second edition of Aston's book was published in 1942!) Intensive research connected with the atomic bomb project has developed the mass spectrograph beyond all pre-war expectations.

Among Aston's most prophetic utterances is the one to the effect that the nuclear physicist "will transmute and synthesise atoms as his elder brother has done molecules. I foresee a time, not immeasurably far distant, when it will be possible for us to synthesise any element whatever, wherever and whenever we please—alchemy indeed in the service of man."

The death is reported in *Nature* (November 14 issue, p. 621) of NIKOLAI IVANOVICH VAVILOV, one of the most remarkable botanists the world has ever known. According to the obituary notice in *Nature* by Dr. C. D. Darlington and Dr. S. C. Harland, the date of Vavilov's death is uncertain, but it was after December 1941.

Son of a textile manufacturer, he was born in 1885. His brother is S. I. Vavilov, now president of the Academy of Sciences. Before the 1914-1918 war he worked under Bateson at the John Innes Horticultural Institution in Merton Park.

Vavilov's expeditions in search of plants that would shed light on the origins of cultivated species are world famous. The first of these, to Persia and adjoining countries, he undertook in 1916 and later he organised and carried out a series of expeditions to Afghanistan, Abyssinia (the Abyssinian expedition cost but £1000!), China, and South America. As the *Nature* obituary points out, Vavilov's potato collection led to the establishment of the British Empire Potato Collection. When he was director of the Lenin Academy of Agricultural

Science, the walls of his office in the Stroganoff Palace in Leningrad were decorated with maps of his expeditions. (Readers will find an interesting pen portrait of Vavilov in J. G. Crowther's *Soviet Science*.)

He was selected by Lenin to preside over the Lenin Academy of Agricultural Sciences and the Institute of Applied Botany, and came to have under his control an enormous organisation of some 400 research and experimental stations with about 20,000 workers on their staffs. Of Vavilov, Crowther has written, "His charm, and gifts of leadership, energy and intellectual power make everyone his friend, and his great achievements have secured universal admiration"; further insight into his personality is given by the remark of Dr. Darlington and Dr. Harland, "His unsleeping mind, his untiring body, his ambitious plans, even his flamboyant showmanship were all Napoleonic in character"—though perhaps a resemblance to Peter the Great (in most respects except his stature) would give a still closer impression of the man.

Vavilov's star seemed to decline after the ill-famed genetics controversy in which he and Lysenko were the outstanding figures. Politics and economics rather than scientific considerations gave a temporary victory to the Lysenko school, but in the period of that success, which is likely to prove short-lived, Vavilov apparently lost his executive posts. Outside Russia Vavilov's fame has never dimmed, and in 1939 the International Congress of Genetics did him the honour of inviting him to preside over their meeting held that year, an honour which, however, he had to decline.

JUNIOR SCIENCE

About Atoms—III

In the last two issues we talked about the structure of atoms and about the nature of elementary particles. We will round off this picture of the atomic world by finding out which parts of the atom are responsible for the different aspects of matter.

You will remember that a typical atom consists of a tiny nucleus which is surrounded by a "cloud" of electrons encircling it. In solid matter like stone, metals and ice, the outer fringes of these electron clouds almost touch each other. The strong force which keeps a lump of iron together is vested in the outermost electrons, and it is due to the fact that neighbouring atoms share the use of one or more electrons. This exchange of electrons, which results in a very strong force, is a peculiarity of the atomic world for which there is no counterpart in everyday experience. We have to remember (as I said last time) that electrons are not just tiny billiard balls or marbles but that they have properties which are very different from the lumps and specks of matter which we can see or feel.

Though we cannot hope to imagine the nature of these "exchange forces", we can easily measure them. As you know, a certain amount of heat is needed to melt a pound of iron or a pound of ice. This energy is used to wrench the atoms or molecules apart and it is thus a measure of the force with which the atoms in solid matter are kept together.

The chemical properties of substances, too, depend on these outermost electrons. For instance, the inert gases helium and neon which do not combine chemically with other substances have well rounded off electron clouds. On the other hand, metals which are very active chemically, e.g. sodium and potassium, have one electron that moves in an orbit much wider than the rest. These electrons which, so to speak, stick out of the metal atoms are those which are shared by neighbouring atoms and this explains why metals are conductors of electricity. The lonely electrons are, on the whole, so far away from the nucleus that they are free to move from atom to atom and can, by their movement, transport electricity. An electric current flowing in a metal wire corresponds to a stream of the electrons belonging to the fringes of the atomic electron clouds. This shows, incidentally, that a current in a wire is a a stream of *negative* electricity and that, contrary to the assumptions of the last century, *electricity flows from the negative to the positive terminal* and not vice versa.

The electrons have practically no weight at all and this means that the weight of things is concentrated in the tiny nuclei of the atoms. The particles, the protons and neutrons, forming these nuclei, are kept together by forces similar to those responsible for the cohesion of a bit of iron. However, the protons and neutrons are obviously not kept together by an exchange of electrons, and for a long time the very strong forces of the nucleus remained a complete mystery. It is generally assumed now that apart from protons and neutrons there is a third kind of particle inside the atomic nucleus, the *meson*. This new particle was discovered a few years before the war and not very much is known about it. It has a negative charge like an ordinary electron but is about 200 times as heavy. Most scientists believe that the protons and neutrons in the nucelus are bound together by an exchange of these mesons.

It is clear that this meson force must be very strong. The protons in the nucleus are all positively charged, and, since equal charges repel each other, the protons would fly apart with great violence if there were not a force to hold them together. This violent repulsion of positive electric charges occurs in the release of atomic energy and it is the breaking of the cohesive force of the nucelus which causes the explosion of the atomic bomb.

K. M.

Night Sky in January

The Moon.—New moon occurs on January 3d. 12h. 30m., U.T., and full moon on December 17d. 14h. 46 m. The following conjunctions take place:

January			
1d. 15h.	Mercury in conjunction with the moon	Mercury	0.2° N.
17d. 04h.	Saturn ,,	Saturn	2 S.
17d. 07h.	Mars ,,	Mars	2 N.
24d. 11h.	Jupiter ,,	Jupiter	4 S.

The Planets.—Mercury rises at 6h. 25m. and 7h. 13m. at the beginning and middle of January respectively, and almost with the sun on January 31. Venus rises about 20 minutes before the sun on January 1 and just before the sun on January 15. At the end of the month the planet rises 15 minutes after the sun. Mars, in the constellation of Cancer at the beginning of January, later on moving into the constellation of Gemini, rises early in the evening—at 17h. 07m. on January 1 and at 14h. 05m. on January 31. On January 14 the planet is in opposition with the sun. The distance of Mars from the earth varies from 60 to 64 million miles between January 1 and 31. Jupiter, in the constellation of Virgo, rises at 1h. 36 m. on January 1 and just before midnight on January 31. Between these dates the distance of the planet from the earth varies between 523 and 478 million miles. Saturn, in the constellation of Gemini, sets at 8h. 54m., 7h. 52m., and 6h. 50m. at the beginning, middle, and end of the month respectively. On January 1 the planet is 752 million miles from the earth and on January 31 the distance has increased to 756 million miles. Saturn is in opposition with the sun on January 12.

Times of rising and setting of the sun and moon are given below, the latitude of Greenwich being assumed:

January	Sunrise	Sunset
1	8h. 06m.	16h. 00m.
15	8h. 00m.	16h. 19m.
31	7h. 41m.	16h. 46m.

January	Moonrise	Moonset
1	5h. 04m.	13h. 57m.
15	14h. 03m.	6h. 00m.
31	6h. 56m.	14h. 42m.

There will be a partial eclipse of the sun on January 3, invisible at Greenwich.

The earth reaches perihelion on January 2 when its distance from the sun is about 91,840,000 miles.

The constellation of Gemini, in which Mars and Saturn are seen during the month, has some interesting stars. Castor and Pollux (α and β Geminorum) are easily recognised, but Pollux is the brighter of the two stars, although it is β Geminorum. Possibly when the stars were given their names first, Castor was the brighter and hence received the name α Geminorum, but it has faded slightly since. Castor is a double but this cannot be detected with binoculars. ζ Geminorum is an interesting variable, fluctuating between magnitudes 3 and 4 in a little over 10 days. This variation can be easily detected with the naked eye.

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